

Middlesex University Research Repository

An open access repository of

Middlesex University research

<http://eprints.mdx.ac.uk>

Rice, Adrian Clifford (1997) Augustus De Morgan and the development of university mathematics in London in the nineteenth century. PhD thesis, Middlesex University. [Thesis]

This version is available at: <https://eprints.mdx.ac.uk/6638/>

Copyright:

Middlesex University Research Repository makes the University's research available electronically.

Copyright and moral rights to this work are retained by the author and/or other copyright owners unless otherwise stated. The work is supplied on the understanding that any use for commercial gain is strictly forbidden. A copy may be downloaded for personal, non-commercial, research or study without prior permission and without charge.

Works, including theses and research projects, may not be reproduced in any format or medium, or extensive quotations taken from them, or their content changed in any way, without first obtaining permission in writing from the copyright holder(s). They may not be sold or exploited commercially in any format or medium without the prior written permission of the copyright holder(s).

Full bibliographic details must be given when referring to, or quoting from full items including the author's name, the title of the work, publication details where relevant (place, publisher, date), pagination, and for theses or dissertations the awarding institution, the degree type awarded, and the date of the award.

If you believe that any material held in the repository infringes copyright law, please contact the Repository Team at Middlesex University via the following email address:

eprints@mdx.ac.uk

The item will be removed from the repository while any claim is being investigated.

See also repository copyright: re-use policy: <http://eprints.mdx.ac.uk/policies.html#copy>

**Augustus De Morgan and the development
of university mathematics in London
in the nineteenth century**

Adrian Clifford Rice

Submitted in partial fulfilment of the
requirements for the degree of

Doctor of Philosophy
awarded by
Middlesex University

January 1997

Abstract

This thesis investigates the teaching of mathematics at university level in London, and in particular by Augustus De Morgan (1806-1871) during his period as founder professor of mathematics at London University (later University College London) from 1828 to 1867. An examination of De Morgan's life and professorial career is followed by a review of changes in instruction at the college under his successors, together with a survey of higher mathematical tuition at other university-level institutions in the capital up to the turn of the twentieth century. Particular attention is paid to original teaching material and the set of students who later achieved distinction in mathematics and other disciplines.

A key feature of the research undertaken for this project has been its intensive use of previously unpublished archival documents, hitherto mostly unstudied. Consequently, much of the information which has been gleaned from these sources (such as De Morgan's lecture material, student notes and contemporary correspondence) has never appeared in print before. The data thus derived has been used in conjunction with publications from the period, as well as more recent works, to produce a contribution to the history of mathematical education which gives a more complete picture of how well nineteenth-century London was served for mathematical instruction than was previously available.

Previous studies of De Morgan have mainly concentrated on his work in algebra and logic, with little or no reference to his mathematical teaching, while published histories of relevant institutions (e.g. University College, University of London) are similarly localised, with few comparisons being drawn with other bodies, and almost no reference to mathematical tuition. By concentrating on the work of De Morgan as a teacher in the context of London mathematics, this thesis will attempt to fill these two important gaps in the literature.

Contents

Preface	vi
Introduction	1
1 Family Background and Education to 1827	7
1.1 De Morgan's Genealogy	7
1.1.1 The Dodson Family	9
1.1.2 The De Morgan Family	12
1.2 De Morgan's formative years	15
1.3 Cambridge	20
1.3.1 The Tripos	20
1.3.2 The Tutors	24
1.3.3 The Student	28
2 From Appointment to Disappointment, 1828-1831	36
2.1 Appointment	36
2.1.1 The Formation of London University	36
2.1.2 The Applicants	38
2.1.3 Babbage and Herschel's involvement	46
2.1.4 De Morgan's Application and Testimonials	49
2.1.5 Inspiration or Desperation?	54
2.2 Initiation	58
2.2.1 Congratulation	58
2.2.2 Preparation	59
2.2.3 Inauguration	67
2.2.4 Teaching and examination	78
2.3 Disappointment	87
2.3.1 Problems	87
2.3.2 Resignation	92
3 The White Period, 1831-1836	98
3.1 A Professor without a Chair	98
3.1.1 The Royal Astronomical Society	101
3.1.2 The Society for the Diffusion of Useful Knowledge	108
3.1.3 De Morgan's educational writings	111

3.1.4 De Morgan's other work for the SDUK	121
3.2 Mathematics and the University	123
3.2.1 De Morgan's replacement	123
3.2.2 The new mathematics course	133
3.2.3 The university situation	141
3.3 De Morgan's Return	150
4 De Morgan and mathematical tuition at University College, 1836-1867	155
4.1 The New University	155
4.1.1 De Morgan's suggestions	155
4.1.2 The University Syllabus	162
4.1.3 De Morgan's criticisms	167
4.2 Mathematics at UCL	173
4.2.1 De Morgan's mathematical tracts	173
4.2.2 The Lower Junior Class	177
4.2.3 The Higher Junior Class	180
4.2.4 The Lower Senior Class	188
4.2.5 The Higher Senior Class	197
4.3 Natural Philosophy at UCL	203
4.3.1 The Jewish professor	204
4.3.2 The incompetent professors	209
4.3.3 The Yorkshire doctor	216
5 De Morgan and his mathematical students, 1836-1867	225
5.1 The Student Experience	225
5.1.1 De Morgan's principal students	227
5.1.2 Student accounts	239
5.2 The Foundation of the London Mathematical Society	252
5.2.1 Background	252
5.2.2 The Society's inception	255
5.2.3 The first year	258
5.2.4 The next year	265
5.3 Final Resignation	269
5.3.1 The Peene bequest	271
5.3.2 The Martineau affair	272
5.3.3 The Aftermath	275

6	Successive Successors - University College after De Morgan, 1867-1900	283
6.1	Pure Mathematics up to 1880	283
6.1.1	Thomas Archer Hirst	285
6.1.2	Olaus Henrici	289
6.2	The Applied Side	292
6.2.1	The Goldsmid chair	292
6.2.2	William Kingdon Clifford	295
6.3	Towards the Twentieth Century	299
6.3.1	The 1884 competition	299
6.3.2	Hill and Pearson	305
7	Mathematics in the Metropolis, 1828-1900	312
7.1	Introduction	312
7.2	King's College	314
7.3	Mathematics for Women	321
7.4	Military Mathematics	325
7.4.1	The Royal Military Academy, Woolwich	325
7.4.2	The Royal Naval College, Greenwich	335
7.5	Technical Education	336
7.5.1	Background	336
7.5.2	The Royal College of Science	337
7.5.3	The Central Technical College	341
7.5.4	Polytechnics	343
7.6	Concluding Comments	345
A	Inventory of De Morgan's Mathematical Tracts contained in the University of London Library	349
B	Lectures on Algebraic Geometry and the Calculus, delivered in University College, London, by Prof. A. De Morgan. Session 1846-1847.	358
C	De Morgan's Final Letter of Resignation	363
	Bibliography	367

Preface

The history of mathematics covers a wide area. While it may be small in comparison to the enormity of history and mathematics themselves, the sheer scope of current research reveals a thriving discipline with many levels of specialisation. Periods currently under investigation range from ancient Mesopotamian mathematics to twentieth century mathematical modelling, with topics as diverse as the role of women in mathematics during the seventeenth and eighteenth centuries, the use of geometry in architecture, and the development of series in Chinese mathematics. As in any subject, with such a huge variety of possible topics to choose from, the question of personal motivation must always arise. It therefore seems appropriate to take this opportunity to explain the process by which the present thesis came to be written.

From 1989 to 1992, I was an undergraduate in the Department of Mathematics at University College, London. While there, I began to come across the name of the nineteenth century mathematician Augustus De Morgan with intriguing regularity. This is not in itself surprising, as any one who has studied mathematics will testify, since ‘De Morgan's Laws’ are now a simple and fundamental constituent of a first-year course in algebra. However, I soon discovered another reason for the repeated use of his name around the department: it was the source of some considerable pride that De Morgan had been the college's founding professor of mathematics as long ago as 1828. Yet, for over three years, those two facts were all I knew about him.

In an attempt to satisfy my increasing curiosity, I took a course on the history of mathematics during my final undergraduate year. From that I acquired an insatiable appetite for further knowledge of the subject, and the obvious choice for a research project was an investigation into this obscure former head of department who had derived some algebraic rules a century and a half ago. However, before I could commence my Ph.D., I was advised to take some sort of ‘conversion’ course between the very distinct disciplines of mathematics and its history. Thus the academic year 1992-93 was spent at King's College, London, from where I emerged with an M.Sc. in the history and philosophy of science and mathematics.

During the year at King's, I discussed plans for my intended Ph.D. with my tutor, Professor Donald Gillies, who expressed great interest in the idea. However, he told me that, under his supervision, the thesis would be a much more philosophical work than I had intended, concentrating especially on De Morgan's work on logic rather

than his mathematics. Nevertheless, he was able to put me in touch with someone who would be an ideal supervisor for a historical survey of the kind I envisaged. This was Ivor Grattan-Guinness, Professor of the History of Mathematics and Logic at Middlesex University.

Up to this point, I had not clearly defined exactly what aspect of Augustus De Morgan's life and work I wished to examine. I originally intended my research to be a study of De Morgan alone but, as Ivor soon pointed out, the vast majority of previous work in this area had already concentrated on his algebra and logic, while other related features remained untouched. In particular, three aspects of his career had yet to be investigated:

- his work on behalf of the Royal Astronomical Society, of which he was an active member for over thirty years;
- his publications for the Society for the Diffusion of Useful Knowledge;
- his work as Professor of Mathematics at University College.

Naturally, I chose the third option!

Work on the project began on 10 January 1994 and in the first week of research came the first major find. In the archives of University College, I came across De Morgan's initial letter of application for the mathematics professorship, together with four references. Furthermore, the archives also contained the applications of twenty-eight unsuccessful candidates together with references on their behalf. This was clearly of major significance to my thesis. I was now in a good position to answer my first question: how and why was De Morgan initially appointed to the professorship? The result was my first paper, now incorporated into the second chapter of this thesis. That paper has since been followed by four others, on various matters related to my research, most of which are also to be found in various forms in the current work.

That first discovery, plus the retrieval of many other documents and manuscripts which I have managed to unearth during the past three years, would not have been possible without the invaluable help and assistance of the staff at the various libraries and archives where my work has concentrated. They include the librarians of the British Library, Trinity College, Cambridge, the Bodleian Library in Oxford, and King's College, London. I must also mention Mary Sampson of the Royal Society, Peter Hingley of the Royal Astronomical Society, and Susan Oakes of the London Mathematical Society, who have been particularly helpful. Thanks are also especially

due to the staff at the two libraries where the majority of my work has been done. Firstly, the University of London Library at Senate House, where the efficiency of Julia Walworth, Helen Young and Peter Underwood has helped me enormously. Finally, but certainly not least, my unlimited thanks go to Gillian Furlong, Susan Stead, Kate Manners and all in the manuscripts and rare books room in the library of UCL for putting up with me for the last three years. Without exception, all of these people have made my research a pleasure.

Thanks must also go to my many friends and colleagues in the British Society for the History of Mathematics for their unceasing interest and support. Those who have helped in one way or another (consciously or otherwise) include June Barrow-Green, Janet Burt, Jeremy Gray, Eileen Magnello, Eleanor Robson, David Singmaster and Alison Walsh. Very special and heartfelt thanks must also go to John Fauvel and Robin Wilson at the Open University for their exceptional encouragement of my work. The former has been an indefatigable source of support and inspiration during the course of this project, and I hope will remain so for a long time to come. To the latter I owe many long and enjoyable meetings in Oxford, resulting in numerous discussions on the history of mathematics as well as a joint paper which was written in collaboration with J. Helen Gardner. My thanks go to them both for permission to incorporate material from that paper into Chapter 5.

Help has also been forthcoming from historians of mathematics overseas. I particularly thank the following: Jan Hogendijk, of the University of Utrecht, for his hospitality and good advice; Niccolò Guicciardini, of the University of Bologna, for his thoughtful and constructive criticisms of my work and ideas; Karen Parshall, of the University of Virginia, for all her help with my papers for *Historia Mathematica*; and Maria Panteki, of the University of Thessaloniki, for her colourful correspondence on all things De Morganian!

This thesis could not have been written without the constant support of my two supervisors, Tony Crilly and Ivor Grattan-Guinness. Tony has played a solid supporting role as my second supervisor; invariably available for friendly advice or just a chat, he has always been willing to offer any help he can, whatever the subject. His knowledge of nineteenth century British mathematics in particular has also proved a very valuable resource which I have taken the opportunity to plunder on many occasions. My thanks to Ivor are unbounded: he has been the perfect supervisor. From our first meeting, he has been an unrivalled source of enthusiasm and stimulation, inundating me with relevant articles, papers and references (by himself

and others) from that time onwards. He has been able to put everything I find into both its mathematical and historical context, while at the same time appearing genuinely surprised at particular revelations. I thank him for his advice, his criticisms and his conscientious devotion to his student, above and beyond the call of duty. In particular, I thank him for letting me take up so much of his last three years without complaint.

Research for this thesis was undertaken under a grant from the British Academy, to whom I would like to express my gratitude for providing a financial incentive to complete the work on time! Finally, I thank my family, in particular my mother and father, for their encouragement and support. This thesis would never have been written without the help of all of these people. So now you know who to blame!

London, 18th December 1996

A. RICE

Introduction

To the historian of mathematics, the name of Augustus De Morgan (1806-1871) is a familiar one. He is remembered not only as a mathematician, but also for his extensive work in logic, and his popular writings on mathematical and scientific subjects. A prolific writer throughout his career, he published eighteen books, over 160 papers, and countless unsigned articles in numerous journals and magazines. Indeed, he was one of the most respected and influential British mathematicians of his day. But there is one aspect of his career which has hitherto received comparatively little attention: his work as a mathematics teacher.

For a period of over a third of a century, De Morgan was the founding professor of mathematics at University College London, during which time his students included the economist and logician William Stanley Jevons, political and constitutional author Walter Bagehot, and the mathematician James Joseph Sylvester - among many others. By the time he retired in 1867, he had established a reputation as one of the foremost teachers of mathematics in the country. It is this less-celebrated aspect of De Morgan that this thesis will investigate. But first, as a prelude, we give a brief introductory survey of his main scientific achievements, together with some idea of the personality behind them.

While anyone who has taken a degree-level course in logic or set theory will be aware of ‘De Morgan’s Laws’, to the majority of today’s mathematicians, the rest of his mathematical work is relatively unknown territory. It is highly unlikely, for example, that many would be aware that, when they use the phrase ‘mathematical induction’, they are employing a term invented by him in 1838. His contributions to algebra are similarly obscure today, yet they were an important ingredient in the growth of symbolic algebra during the nineteenth century, materially assisting in the increasing trend towards abstraction during that period. Furthermore, his research in this area was acknowledged by William Rowan Hamilton as having influenced the development of quaternions.

De Morgan was also one of the first British mathematicians of the nineteenth century to work in mathematical analysis, his most enduring legacy in this subject being a rule for determining the convergence of infinite series. (This states that if a series can be written as

$$\sum_{n=1}^{\infty} \frac{1}{f(n)}$$

then if

$$e = \lim_{n \rightarrow \infty} \frac{n f'(n)}{f(n)}$$

the series converges for $e > 1$, but diverges for $e \leq 1$.)¹

Perhaps best remembered today for his research into logic, De Morgan was described by Charles Peirce as "the greatest formal logician that ever lived".² Like his contemporary George Boole - with whom he frequently corresponded on logical and mathematical matters for many years³ - De Morgan attempted to use mathematical ideas in his logic, his work strongly encouraging Boole's own research in this area. However, unlike Boole, De Morgan was primarily concerned with extending the old Aristotelian system rather than creating a new one, although his invention of a logic of relations was a major contribution, substantially increasing the scope of the subject.

De Morgan also attempted to make his logic more quantitatively precise. Believing the traditional syllogistic method to be inadequate in any reasoning involving quantity, he asserted that arguments of the form

Most of the Ys are Xs
Most of the Ys are Zs
 \therefore Some Xs are Zs

could not be proved by means of any of the normally accepted Aristotelian syllogisms.⁴ In order to rectify this defect, he introduced the notion of *quantifying the predicate* into his logic. In other words, he said that if the total number of Ys was m , the number of Ys that are Xs x , and the number of Ys that are Zs y , then there are at least $(x + y - m)$ Xs that are Zs. For example, given that a boat with 100 people on board sinks, if 55 were below deck and the total number drowned is 70, then, by De Morgan's reckoning, at least 25 (i.e. $55 + 70 - 100$) people below deck were

¹ Augustus De Morgan, *The Differential and Integral Calculus*, (London: SDUK, 1842), 235-236; Charles C. Gillispie (ed.), *Dictionary of Scientific Biography*, 4, (New York: Scribner's, 1970), 35-37, p.35.

² Augustus De Morgan, *On the Syllogism, and other logical writings*, (ed. Peter Heath), (London: Routledge and Kegan Paul, 1966), xxx.

³ Gordon C. Smith, *The Boole-De Morgan Correspondence 1842-1864*, (Oxford: Clarendon Press, 1982).

⁴ A. De Morgan, *op. cit.*, (2), 9.

drowned. His work on extending the syllogism was thus principally successful in developing a numerically definite system of logic: a significant step forward.

As with his algebra, De Morgan aimed to construct a purely symbolic language, in which all reasoning could be carried out. To this end, he developed notation to describe simple propositions. For example:

Every X is a Y	was denoted by	X)Y
No X is Y	" " "	X.Y
Some Xs are Y	" " "	XY
Some Xs are not Ys	" " "	X:Y

He then worked out rules to establish valid syllogistic inferences, such as

$$\begin{aligned} X)Y + Y)Z &= X)Z \\ Y:X + Y)Z &= Z:X \end{aligned}$$

However, while his attempts to construct a symbolic approach to logic were certainly innovative, his notation was subsequently superseded by Boole's more algebraic system. An illustration of this is provided by the fact that his aforementioned laws are far more familiar to us in their modern Boolean formulation:

$$(A \cup B)' = A' \cap B', \quad (A \cap B)' = A' \cup B'$$

De Morgan, like Boole, was one of the few mathematicians of his time to realise the importance of logic to mathematics, and vice versa. But he also recognised that this view was not shared by the larger mathematical community. As he later characteristically put it:

We know that mathematicians care no more for logic than logicians for mathematics. The two eyes of exact science are mathematics and logic: the mathematical sect puts out the logical eye, the logical sect puts out the mathematical eye; each believing that it sees better with one eye than with two.⁵

In addition to his work in mathematics and logic, De Morgan had a lifelong fascination for the history and philosophy of science in general, and mathematics in particular.⁶ He contributed over 700 articles to a publication entitled the *Penny*

⁵ *The Athenæum*, No. 2125, 18 July 1868, 71.

⁶ Adrian Rice, Augustus De Morgan: historian of science, *History of Science*, **34** (1996), 201-240.

Cyclopædia on all areas of mathematical science, many of which were historical. Other papers, such as ‘The early history of infinitesimals in England’ and ‘Notices of English mathematical and astronomical writers between the Norman Conquest and the year 1600’, give a mere indication of the breadth of his knowledge and interest in the subject. Though deeply interested in philosophy, this mode of thought was not usually one of his strengths. As he wrote, he "had no objection to Metaphysics, far from it, but if a man takes a candle to look down his own throat, he must take care not to set his head on fire".⁷

Even the briefest study of his works shows De Morgan to be an intriguing character whose enormous intellect was matched only by a sharp wit and keen sense of humour. This is best evinced in what is perhaps his most enjoyable work, *A Budget of Paradoxes*, a collection of humorous writings and reviews featured in a weekly Victorian periodical called *The Athenæum*, to which he was an active contributor for thirty years. In addition to numerous anecdotes and witty passages, it also features a parody of a verse by Swift which has since become a familiar saying - although few would know its author:

Great fleas have little fleas, upon their backs to bite 'em,
And little fleas have lesser fleas, and so *ad infinitum*.⁸

De Morgan was a man of many eccentricities. When asked his age, he is reputed to have declared: "I was x years of age in the year x^2 "⁹ - a phenomenon peculiar to those born in years such as 1640, 1722, 1806, 1892, 1980, and so on. In 1859, when offered an honorary law doctorate by Edinburgh University, he declined it, saying that he "did not feel like an LL.D."¹⁰ He also refused to allow himself to be proposed as a Fellow of the Royal Society. "Whether I could have been a Fellow," he later said, "I cannot know; as the gentleman said who was asked if he could play the violin, I never tried."¹¹

In recent years, there has been a resurgence of interest in De Morgan, with much of his research work coming under renewed scrutiny from historians of science. In

⁷ Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, & Co., 1882), 96.

⁸ Augustus De Morgan, *A Budget of Paradoxes*, (London: Longmans, Green, and Co., 1872), 377.

⁹ Alexander MacFarlane, *Lectures on Ten British Mathematicians of the Nineteenth Century*, (London: Chapman and Hall, 1916), 19.

¹⁰ S. E. De Morgan, *op. cit.*, (7), 269.

¹¹ A. De Morgan, *op. cit.*, (8), 18.

particular, scholars such as Helena Pycior¹² and Joan Richards¹³ have re-evaluated De Morgan's algebraic work, while Daniel Merrill¹⁴ and Maria Panteki¹⁵ have provided detailed assessments of his contributions to logic. However, to the best of my knowledge, his work as a teacher of mathematics has received no sustained attention. This is particularly surprising, not only in view of the fact that De Morgan's teaching career occupied the majority of his working life, but also because of the wide reputation he attained in this occupation, both in his lifetime and after.

It is for this reason that the present work has been undertaken. Since there is, at present, no published investigation of De Morgan as a professor of mathematics, this thesis will attempt to fill this gap in the literature. The first chapter begins with a survey of his immediate ancestry, followed by an account of his early years and intellectual development, with especial reference to his undergraduate study at Cambridge. Chapter 2 uses previously unpublished documents to discuss his election to the professorship at University College, before concentrating on his initial teaching experience, culminating in his first resignation.

Chapter 3 deals with De Morgan's five-year absence from teaching, discussing his work during this period, especially his writings on mathematical education. It also examines mathematical instruction at the college under his successor, as well as the circumstances which led to his eventual return as professor in 1836. Although the principal subject of Chapter 4 is De Morgan's mathematical tuition at University College between 1836 and 1867, it also provides information on the teaching of natural philosophy at the college, plus De Morgan's opinions on the recently-established University of London. However, the chief component of this chapter is an analysis of his mathematical course, based on over 300 manuscript notebooks, which provide a close insight into the material covered in his lectures.

Chapter 5 shifts the focus to his principal students during this period, using their own accounts to form some evaluation of their experience of his teaching. This leads on to the related theme of the origin of the London Mathematical Society, founded, towards the end of De Morgan's career, in 1865. The chapter closes with a

¹² Helena M. Pycior, 'Augustus De Morgan's Algebraic Work: The Three Stages', *Isis*, **74** (1983), 211-226.

¹³ Joan L. Richards, 'Augustus De Morgan, the history of mathematics, and the foundations of algebra', *Isis*, **78** (1987), 7-30.

¹⁴ Daniel D. Merrill, *Augustus De Morgan and the logic of relations*, (Dordrecht: Kluwer Academic, 1990).

¹⁵ Maria Panteki, *Relationships between algebra, differential equations and logic in England: 1800-1860*, (C.N.A.A. Ph.D. Thesis, 1992).

discussion of the events surrounding De Morgan's final resignation in 1866. The final two chapters place the preceding material in its appropriate context. Chapter 6 documents the changes in mathematical teaching at University College from De Morgan's resignation to the turn of the century, while Chapter 7 surveys the provision of university-level mathematical instruction elsewhere in the capital throughout the period covered by the previous chapters.

The main text is followed by three appendices. Appendix A provides a complete catalogue of De Morgan's mathematical tracts used in Chapter 4. Appendix B reproduces the notes of one of his students from a lecture on conic sections delivered on 13 March 1847. Finally, Appendix C reproduces, in full, his final letter of resignation from 1866. A full list of all sources used, published and archival, will be found in the bibliography.

Chapter 1

Family Background and Education to 1827

1.1 De Morgan's Genealogy

Augustus De Morgan could trace his ancestry back to a century before his birth on both maternal and paternal sides. Yet information concerning the De Morgan family prior to the beginning of the eighteenth century was, and is, extremely scarce. The family is particularly intriguing as, for three generations, they served as soldiers of the British Army, stationed in India - with a French surname. This name is also interesting, not just because of its rarity, but on account of its possible origins. Indeed, De Morgan himself was wont to speculate on the derivation of his family name, although, as the following passage indicates, not always without some element of tongue-in-cheek:

The name *Morgan* signifieth *born of the sea*. The word *Mor*, of the same root as *mare*, is in British the *sea*, as Camden and others testify, and *gan* containeth the root of $\gamma\epsilon\nu\omicron\zeta$. It hath ever been a tradition that this, and no other, is the meaning. Thus Edward Phillips, the nephew of John Milton, saith of Morgan in his *World of Words* that it is "a proper name of man, signifying in the ancientest British tongue as much as Seaman". ... This word Morgan is once and again found in the vulgar tongue. Thus the Italians do call an appearance which ariseth from the sea by the name of *Fata Morgana* : and the Bretons will have it that the mermaid shall be called Mary *Morgan*.¹

The greatest likelihood was that the name and family were of French origin and, being of Protestant descent, the most likely cause of their emigration to England was the renunciation of the Edict of Nantes by Louis XIV in 1685. This had resulted in a wave of French Protestant refugees, or Huguenots, arriving in Britain at the end of the seventeenth century, among them the mathematician Abraham de Moivre (1667-1754)². While in France, the De Morgan family would probably, like de Moivre, have written their name with its first letter in the lower case, viz. "de Morgan". However, by the time of Augustus, the convention had changed to using a capital D at the beginning; a practice

¹ Augustus De Morgan, "Memorandums on the Descendants of Captain John De Morgan...", University College London Archives, MS. ADD. 7, ff.101-102.

² Best known for the theorem which bears his name: $(\cos x + i \sin x)^n = \cos nx + i \sin nx$, although he never proved it.

which he was quick to correct if not obeyed by others.³ He would have been very annoyed to find his name listed in an index under the letter M!

De Morgan's interest in his heritage and background led him to compile a manuscript book on his family history which has thankfully survived to the present day. Though never intended for publication, one imagines that almost as much work went into its preparation as into a finished volume. He provides a thorough catalogue of De Morgan family members in his own and the previous three generations not only in his direct line of descent but also including great aunts and uncles, cousins, nieces and nephews, the majority of whom he would never have known. The volume is fully referenced, with occasional cuttings or pictures from journals and magazines pasted in to provide further information. In short, judging from the tremendous amount of time and effort he must have spent in amassing this family chronicle, one can be in no doubt that De Morgan's ancestry was of great importance and interest to him.

Once again, De Morgan's characteristic sense of humour is in evidence at various points in the text, such as the opening preface: "Such account as I can give of my family is contained in two books. The first is well known by the name of Genesis, ascribed by Jewish tradition to Moses. The second is this book itself, which my own handwriting will identify as compiled by me. Moses gave no account of his materials: I have given what I could. Moses wrote in Hebrew: I in English. Moses was a public writer, I am a private one. Many are the oppositions between me and Moses: but the one which is most to the point is this. Our grammars are alphaic and omegatic. His motto is απογραμμηζ α'ρχεσξαι; and mine may be επ'ακραν ηκομεν γραμμην, to which those shall add κακων who think us a bad set. But in truth we were always decent enough: too many of us were soldiers, and that is the worst; or got their living by dying, as the epigram hath it."⁴ A family tree is then sketched out, beginning with Adam and Eve. Between these renowned forebears and his great-grandfather is inscribed: "This is a long interval, and contains some very celebrated cousins as Confucius, Alexander the Great, Judas Iscariot, Praise-God Barebones, Archie Armstrong, Sir I. Newton, &c, &c..."⁵

³ In a letter of 16 May 1852, he corrects his friend Sir William Rowan Hamilton for such an error: "Imprimis - slip 92:- De Morgan - not de Morgan - when I was at Cambridge, I used to *get* out of my misery in *viva voce* examinations sooner by M-D than I should otherwise have done, by insisting on this capital arrangement." - Robert Perceval Graves, *Life of Sir William Rowan Hamilton*, vol. 3, (Dublin: Hodges, Figgis, & Co., 1889), 364.

⁴ A. De Morgan, *op. cit.*, (1).

⁵ *ibid.*

So begins De Morgan's account of his family history, from which valuable unpublished document we are able to derive almost all information concerning his genealogy and early life. The only other relevant sources are Sophia De Morgan's biography of her husband, published eleven years after his death, in 1882, and a biography of their eldest son, William, from 1922. These employ some, but by no means all, of the mass of information contained in the manuscript; but what makes them especially useful is that they also act as repositories for stories, anecdotes and other pertinent material which would otherwise have been lost. So, while the number of our principal sources may be very limited, they contain a wealth of data from which the historian can begin to piece together a rough history of the antecedents of Augustus De Morgan, from the early eighteenth century to the time of his birth.

1.1.1 The Dodson Family

De Morgan's knowledge of his maternal lineage began with perhaps the most famous of all his ancestors, at least in his day.⁶ James Dodson was a mathematics teacher who lived in the early part of the eighteenth century. Virtually nothing is known about his early life except that at some time, probably in early adulthood, he appears to have studied under Abraham de Moivre. This is revealed in an obscure biography by Matthew Maty, published around 1756, entitled *Mémoire sur la vie et sur les écrits de Mr. A. de Moivre*:

C'est aux personnes qui savent lire les écrits de Mr. de Moivre, à lui assigner son rang. Les autres peuvent juger de lui par les amis qu'il a eus, et les disciples qu'il a formés. Newton, Bernoulli, Halley, Varignon, Sterling, Saunderson, Folkes, et plusieurs autres, farent dans la première liste. Macclesfield, Cavendish, Stanhope, Scot, Daval, et Dodson, se trouvent dans la seconde.⁷

Described by Charles Hutton as "an ingenious and very industrious mathematician",⁸ Dodson was best remembered in De Morgan's day for two mathematical works, the first of which, *The Anti-Logarithmic Canon*, was published in 1742. This was "a Table of Numbers, consisting of Eleven Places of Figures, corresponding to all Logarithms under

⁶ Augustus De Morgan, Some Account of James Dodson F.R.S., *Journal of the Institute of Actuaries and Assurance Magazine*, **14**, Part V, No.LXXIII, (October, 1868), 341-364.

⁷ Matthew Maty, *Mémoire sur la vie et sur les écrits de Mr. A. de Moivre*, (La Haye: H. Scheurleer, no date), 38-39.

⁸ Charles Hutton, *A Philosophical and Mathematical Dictionary*, 2nd edition, (London: F.C. & J. Rivington, 1815), vol. 1, 433.

100,000"⁹ - a "very great performance"¹⁰ (Hutton's words) which remained unique until 1849.¹¹ De Morgan reckoned that "it must have cost him, altogether, four or five years of work, supposing him to have employed all his leisure, and to have had more leisure than a teacher of mathematics could well have".¹² He thus surmised that "taking the time necessary for the preparation of the Antilogarithmic Canon, he could not have been less than 30 years old when it was published in 1742".¹³

Given also that the book was "a very heavy work requiring years of toil, hardly to be undertaken at his own expense by a man who had a family to support",¹⁴ De Morgan deduced that his great-grandfather had married in 1743. Speculating on how the book came to be published on Dodson's own account, he postulated that it may have been the work of a young enthusiast, who spent his earnings on covering the cost of its eventual publication. "If this be so," De Morgan dryly commented, "the wife who married him when it was finished was not a very prudent woman."¹⁵

The second work by which Dodson had achieved fame, especially in England, was a three-volume collection entitled *The Mathematical Repository*. This was a compilation of algebraic problems and exercises, with applications to probability theory and life contingency problems in the manner of his former tutor. Indeed the first volume, published in 1747, was dedicated to de Moivre, who contributed some of the examples in volume two, published six years later. Perhaps by virtue of these publications, not to mention his connection with a prominent mathematician, on 16 January 1755 Dodson was elected a Fellow of the Royal Society, being admitted one week later. By now, he was described on his title pages as "Accomptant, and teacher of the Mathematics, ... Bell Dock, Wapping".¹⁶

This situation changed on 7 August that year, when, as a partial result of his Royal Society Fellowship, Dodson was elected master of the Royal Mathematical School at

⁹ James Dodson, *The Anti-Logarithmic Canon*, (London: Printed for James Dodson at the Hand and Pen in Warwick Lane; and John Wilcox, at Virgil's Head, opposite the New Church in the Strand, 1742), title page.

¹⁰ Charles Hutton, *Mathematical Tables*, (London: G.G.J. & J. Robinson, and R. Baldwin, 1785), 119.

¹¹ *Dictionary of National Biography*, **15**, 174.

¹² A. De Morgan, *op. cit.*, (1), f.151.

¹³ *ibid*, f.147.

¹⁴ *ibid*.

¹⁵ *ibid*, f.151.

¹⁶ James Dodson, *The Mathematical Repository*, vol. 2, (London: printed for J. Nourse, 1753), title page, xxiv.

Christ's Hospital in London. This school had been established by Charles II ("who was, for an idler, a bit of a scientific man"¹⁷) to instruct boys in the highest branches of the subject with a view to navigation. Yet, despite this prestigious appointment, it appears that Dodson's descendants were later to look upon the post almost as an embarrassment, as De Morgan found out. His wife tells us: "When quite a boy he asked one of his aunts 'who James Dodson was;' and received for answer, 'We never cry stinking fish.' So he was afraid to ask any more questions, but settled that somehow or other James Dodson was the 'stinking fish' of his family".¹⁸ It took him many years to discover that "James Dodson is the only one of his family...who stands in the *Biographie Universelle*¹⁹...and F.R.S. may mean Fish Remarkably Stinking".²⁰

Dodson's new position, with its increased income and security of tenure, led him to think about taking out life insurance. However, on approaching the Amicable Life Assurance Society, he was refused a policy on account of his age, since they only took lives up to forty-five.²¹ This apparently resulted in his formation of a new society based on a more equitable plan.²² He calculated the tables and premiums on which the new Equitable Society started when it was granted a deed of settlement in 1762. However, Dodson did not live to see his new venture. He died on 23 November 1757 "in very mean circumstances, leaving three motherless children unprovided for, viz. James, aged 15, Thomas, aged 11 and three quarters, and Elizabeth, aged 8".²³ The two youngest children were taken in by Christ's Hospital.

James Dodson the younger was apprenticed to a Mr. Massiter who, we are told by his grandson, "was in some business in the wharfs".²⁴ He was later, "to get the freedom of the city, an apprentice to the Watermans' Company".²⁵ On coming of age, in December 1764 he succeeded to his father's post as actuary of the Equitable Society, although he apparently lacked the elder Dodson's mathematical abilities. He resigned in April 1767 to

¹⁷ A. De Morgan, *op. cit.*, (1), f.136.

¹⁸ Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, & Co., 1882), 233-234.

¹⁹ *Biographie Universelle*, **11**, (Paris: A. Thoisen Desplaces, 1852), 138.

²⁰ A. De Morgan, *op. cit.*, (1), f.136.

²¹ Francis Baily, *An Account of the Several Life-Assurance Companies established in London*, 2nd edition, (London: John Richardson, 1811), 2.

²² John Nichols, *Literary Anecdotes of the Eighteenth Century*, vol. 5, (London: Nichols, Son, and Bentley, 1812), 400.

²³ *D.N.B.*, **15**, 175.

²⁴ A. De Morgan, *op. cit.*, (1), f.152.

²⁵ *ibid.*

take a more suitable position in the Custom House, where he remained until his death on 22 June 1808, aged 65. This puts his birth at around 1743, which is certainly in line with De Morgan's hypothesis of Dodson senior marrying at around that time. Given also that the father was rejected by the Amicable Assurance Society, aged over forty-five, around the time of his appointment to the mathematical mastership (1755), this places his birth at slightly before 1710.

The younger James Dodson also eventually married, although we do not know when, and had eleven children, one of whom was his daughter Elizabeth, born in 1776. Largely because she was female, there is very little record of her life in comparison to her father and grandfather. However, we do know that, by the late 1790s, she was living with her sister and brother-in-law in Ceylon (now Sri Lanka). While there, she met a young British soldier by the name of Captain John De Morgan who was serving in the Madras Infantry. Their marriage in 1798 brought together two families from very different backgrounds: the Dodsons were modest but comfortable middle class professionals; the De Morgans were army officers under the employment of the East India Company, a family tradition which had been established for three generations, beginning at a time almost exactly contemporaneous with the first James Dodson.

1.1.2 The De Morgan Family

The earliest De Morgan of whom record survives is a Captain John De Morgan of the Madras Army who died at Publicat in India on 1 December 1760. It would seem that this De Morgan was born around 1694, the son of a Huguenot refugee. Presumably disillusioned with his poor financial prospects, he joined the East India Company as a soldier, arriving in India on 11 July 1710. He apparently rose through the ranks with some rapidity: "In 1715 he was made Ensign for his bravery in action, and later he became Governor of Forts St. David and Ajengo, occasionally acting in the same capacity at Fort St. George."²⁶ It was at this latter garrison that he married a French woman, Sarah Despomaire, on 2 September 1717. Whether this marriage ended by death or divorce is unknown, but he later "had nine children by Ann²⁷ his wife who died at Negapatum in 1747".²⁸ John De Morgan also had a brother, Lieutenant William De Morgan, "who died of the smallpox at Cuddalore in 1747 or 1748".²⁹

²⁶ Anna M. W. Stirling, *William De Morgan and his Wife*, (London: Thornton Butterworth Ltd, 1922), 22.

²⁷ Ann Turbeville (also entered as "Turville" and "Tivill" in the records) was also French.

²⁸ A. De Morgan, *op. cit.*, (1).

²⁹ *ibid.*

The sixth (and only surviving male) child of John and Ann De Morgan was the first of many in the family to be named Augustus. Born on 2 November 1741, he too attained the rank of Captain in the Madras Infantry. In 1769 he married Christiana Hutteman (1754-1774), the daughter of a Danish missionary, at Cuddalore. Though their marriage was brief, she managed to provide him with three children, George Augustus (1771-1790), John (1772-1816) and Edward (1773-1774), before her own premature death on 25 June 1774. The Captain's own demise followed four years later in rather dramatic circumstances. On 11 October 1778, at the siege of Pondicherry, he was blown up while laying a large gun at his post, an event which, according to the *Gentleman's Magazine*, he had predicted earlier that day: "In 1778..., at the taking of Pondicherry, Captain John Fletcher, Captain Demorgan [sic], and Lieutenant Bosanquet, each distinctly foretold his own death on the mornings of their fate."³⁰

His namesake elucidates:

There is a well believed tradition that the death of my grandfather happened thus. Seeing that his post in the trenches was not properly defended from the view of the enemy (or that the line of the sap produced passed through the town, or something of that kind) he reported the circumstance to the general commanding, who referred it to the chief engineer. This officer laughed and said it was all right; on which my grandfather said, that being the case, he had nothing to do but to make his will.³¹

To his grandson it was indeed ironic "that a gallant soldier constantly exposed to death, did not consider any danger save a flaw in engineering to be a sufficient reason for making his will!"³² However, it proved a prudent measure, since that evening, the Captain was killed, though perhaps not quite in the manner he had predicted. By one account, his head was "taken off while he was calling out to a native officer, and ordering him to leave some very exposed spot"³³, while "Dr Briggs, who married my mother's sister, used to affirm that he was at the siege of Pondicherry, and that my grandfather's head rolled between his legs. But I have heard it asserted that he must have confounded this siege

³⁰ *The Gentleman's Magazine*, 80, part 2, (1810), 33.

³¹ A. De Morgan, *op. cit.*, (1), f.29.

³² Stirling, *op. cit.*, (26), 23.

³³ A. De Morgan, *op. cit.*, (1), f.29.

with some other."³⁴ In any event, whether due to the loss of Captain De Morgan's head or not, the town fell six days later.

At this time, the Captain's two surviving sons, George Augustus and John, were at school in England. Aged only seven and six respectively, they were placed in the care of guardians, who apparently had far more concern for the investment of their money than the welfare of the children. Indeed, so intense were their disputes over finances that the boys were soon forgotten. By the time the guardians came to inquire about their charges, the school had been dissolved due to bankruptcy, with the result that the whereabouts of the two young boys was unknown. De Morgan tells us:

Hue and cry was raised, Bow Street officers were employed, and at last the two little boys were found in the possession of a worthy old couple in Monmouth Street, who had found them in the street, for aught I know, and having no children had determined on adopting them. The boys had been there long enough, having never known their father, to imagine that the old people were their father and mother. They had left India very early. The foster parents sold old clothes, and my father was found in a man's coat, with the skirts on the ground, and the sleeves tucked up. This I have often heard from my mother, to whom my father related that he well remembered going out every evening to fetch the beer for his *daddy* in the long coat.³⁵

Both sons eventually returned to India, where they joined the Madras Army. George Augustus De Morgan, the elder of the two, was in the cavalry and was killed at the age of nineteen during his first active service, although his body was never found. His brother John obtained his cadetship in 1789, being stationed in Ceylon for some time. It was there that he met Elizabeth Dodson, who he married at Columbo on 4 August 1798. Of this wedding, their son later recalled:

When I was married, in 1837, at the Registrar's Office in the Hampstead Road, my mother disliked the mode, and said 'Why are you not married in a church, as your father was before you?' She had adopted the tone of the world in general, forgetting that she was married in the drawing room of the chief civil servant at Columbo, by Mr Rosenhagen,³⁶ who had the gout so bad that he could not stir from his chair, or rather from his *chairs*, one

³⁴ *ibid.*

³⁵ *ibid.*

³⁶ Philip Rosenhagen: see *The Athenæum*, No. 1609, 28 Aug. 1858, 268.

for his general self, the other for his leg, and who was a model of riotous living and unclerical notoriety.³⁷

John De Morgan had probably reached the rank of captain by the time of his marriage and with the increase of position came several changes in postings: Madras in 1799, followed by Masulipatam in 1800 and Pondicherry in 1801. At each of these separate postings were born his first three children, John Augustus, James Turing, and Eliza De Morgan. The two sons were tragically lost at sea, off the Cape of Good Hope, on their way to school in England, around June 1804. The family returned to Madras, where another daughter, Georgiana, was born in 1805. By this time, the elder De Morgan had been promoted to the rank of colonel and was offered a choice of battalions of his regiment to command. The first was stationed in Vellore, the second in the holy town of Madura (now called Madurai).

Vellore was a gay place and Madura was dull. He had been disappointed of a staff situation which he expected, and was in low spirits and sulky; he therefore chose Madura.³⁸

The choice was a fortunate one, since this was a time when the native troops' hatred and distrust of English officers was reaching a critical level. This disaffection resulted in the mutiny of the Vellore battalion on 10 July 1806 in which several English officers were killed, including the colonel in command. The mutiny was a particularly significant event for Colonel De Morgan in two respects. Most obviously, had he chosen to command the battalion at Vellore, he would probably have been killed by the mutineers. More symbolic, however, was the fact that it occurred two weeks after the birth of his fifth child, and first surviving son, Augustus De Morgan.

1.2 De Morgan's formative years

Born on 27 June 1806, Augustus De Morgan was found at birth to have the use of only one eye: his left. Many years later he wrote: "When I was in preparation, my mother attended much to a favourite native servant (in India) who had the ophthalmia, which they call the *country sore eyes*. When I was born it was found I had had it too, and one eye was not destroyed, but never completely formed: it is only a rudiment, with a

³⁷ A. De Morgan, *op. cit.*, (1), f.29*.

³⁸ *ibid*, f.116.

discoloration in the centre, which shows that nature intended a pupil. ... Accordingly I have always been strictly unocular. I have seen as much with my right eye as with any one finger - no more, and no less."³⁹ This distinctive physical peculiarity was soon to result in his concentration on mental rather than physical activities.

Although the country of his birth was later to be a source of much pride for De Morgan, he was there for only four months. On 22 October, the De Morgan family set sail for England on the *Jane, Duchess of Gordon* in a convoy of nearly forty ships. Colonel De Morgan's motives for this decision were probably to ensure his family's safety in the light of the recent unrest, although it is also possible that his wife had expressed a wish to return home as her sister had also done. After a voyage of nearly six months, their ship landed at Deal in Kent on 12 April 1807. "At this period," comments De Morgan, "I had passed three-fifths of my life on the water".⁴⁰ He was later to use this voyage as an excuse for his aversion to travelling: "I consider I had my share of it in my nurse's arms, in which I began life with a journey of 11,000 miles, crossed the line twice, and knew nothing about it all - Heaven be praised."⁴¹

After some time in London, Colonel De Morgan settled his family at Worcester so that his wife might be close to her sister. He returned to India alone in 1808, for a period of two years. On his return, the family moved to north Devon, first to Appledore, and then to Bideford. It was here that, at the age of just over four years old, the education of Augustus De Morgan began with lessons from his father in "reading and numeration".⁴² In 1812, the family moved again, this time to Barnstaple, where he was taught reading, writing and spelling by a Miss Williams, "afterwards Mrs Oram"⁴³. The Colonel's imminent departure to India for another tour of duty occasioned a final move to Taunton in Somerset, from where he departed on 29 January 1813. He never saw his family again.

Despite being an honourable soldier and a good officer, John De Morgan was apparently a man of very strong principles with a tendency to speak plainly when he felt justified, no matter how trivial the matter or who he offended, a trait he passed on to his son. It was this characteristic which would lead indirectly to his death. Shortly after his arrival in

³⁹ Robert Perceval Graves, *Life of Sir William Rowan Hamilton*, vol. 3, (Dublin: Hodges, Figgis, & Co., 1889), 612-613.

⁴⁰ A. De Morgan, *op. cit.*, (1), f.116.

⁴¹ Graves, *op. cit.*, (39), 525.

⁴² S. E. De Morgan, *op. cit.*, (18), 3.

⁴³ A. De Morgan, *op. cit.*, (1), f.155.

Madras, Colonel De Morgan was put in charge of a battalion at Quilon. However, following a dispute over a minor detail with a superior officer, he was transferred to Mosulipasam, a far less hygienic post, where he was soon attacked by a liver complaint. He was ordered home and embarked for England shortly afterwards. His only attempt at a diary during his voyage is, in pencil, "1816 Sept 27 Left Madras in the Larkins E.I. Capt. Dumbleton, sick with liver".⁴⁴ He died near St. Helena in either November or December 1816.

Meanwhile in Taunton, the young De Morgan's education continued in his father's absence. Between the ages of seven and eight, he was taught "reading, writing, arithmetic, and (very) general knowledge"⁴⁵ by a "Mrs Poole, assisted by her relative - Pearson, an American".⁴⁶ That tuition was continued by his next two teachers, the Rev. J. Fenner and the Rev. T. Keynes, the former being a Unitarian and the latter an independent minister. It was under the guidance of the Rev. H. Barker, from July 1819 to June 1820, that the pupil first encountered *mathematics* (as opposed to mere arithmetic), being taught "Latin, Greek, Euclid, Algebra, and a little Hebrew".⁴⁷

At the age of fourteen, De Morgan was sent away to a school in Redland, near Bristol, run by the Reverend John Parsons.⁴⁸ Parsons had studied at Oxford, where he received his M.A. in 1807. For the next five years he had been a Fellow of Oriel College, before being made vicar of Marden, Wiltshire, in 1816.⁴⁹ As an Oxford man, Parsons was a good classical scholar, so, while he taught the usual school syllabus of Latin, Greek and mathematics, "his aim was rather to make his boys good classics than mathematicians".⁵⁰ It is not known how long he had been running his school before De Morgan's arrival in July 1820 but, by all accounts, he was a good teacher. De Morgan certainly retained a lasting respect for him, even though "he was not a high mathematician".⁵¹

It was around this time that the boy's hitherto uncultivated mathematical skill was first recognised, though not by Parsons. We are told, in a typically verbose manner, that "the first suspicion of Augustus having inherited the ostensibly reprehensible proclivity of his

⁴⁴ *ibid*, f.128.

⁴⁵ S. E. De Morgan, *op. cit.*, (18), 3.

⁴⁶ A. De Morgan, *op. cit.*, (1), f.155.

⁴⁷ S. E. De Morgan, *op. cit.*, (18), 3.

⁴⁸ Died 31 July 1844 at Bath. - *Gentleman's Magazine*, **22**, (1844), 327.

⁴⁹ Joseph Foster, *Alumni Oxonienses 1715-1886*, **3**, (London: Joseph Foster, 1888), 1076.

⁵⁰ S. E. De Morgan, *op. cit.*, (18), 7.

⁵¹ *ibid*, 3.

maternal forbear was due to a mere chance",⁵² the propensity being "accidentally developed, and indeed made known to its possessor"⁵³ by a family friend who, on finding him making an elaborate drawing of a figure from Euclid with ruler and compasses, initiated him into the concept of a mathematical proof. Thus the young De Morgan was abruptly made aware of "the mine of wealth that only required working...and from that time his great delight was to work out questions which were often as much his own as their solution".⁵⁴

From this point, his mathematical progress was rapid, as a school-friend, Robert Reece, later testified:

It seems an odd thing to record, but I well remember that I was advanced in "Bland's Quadratic Equations"⁵⁵ when De Morgan took up that well-known elementary book, "Bridge's Algebra,"⁵⁶ for the first time. But it was so. He read Bridge's book like a novel. In less than a month he had gone through that treatise and dashed into Bland, and so got out of sight, as far as I was concerned.⁵⁷

Some evidence of De Morgan's mathematical development during this period has been preserved in a single exercise book dating from his time at Redland. Bearing the date 1822, it contains mathematical notes and exercises undertaken by him at around the age of sixteen. It would appear to have been written at a time precisely contemporaneous to Reece's recollection, since the first half of the book comprises "Simple Equations containing two Unknown Quantities",⁵⁸ taken from Bland's *Algebraical Problems*. These involve the simultaneous solution of either linear or quadratic expressions; hardly the most intellectually challenging of problems, but certainly above average difficulty for the typical schoolboy of that age.

However, it is apparent that the young De Morgan did not take long to exhaust Bland's supply of problems. His swift progress in algebra is evinced by the book's later pages

⁵² Stirling, *op. cit.*, (26), 25.

⁵³ S. E. De Morgan, *op. cit.*, (18), 4.

⁵⁴ *ibid.*

⁵⁵ Miles Bland, *Algebraical Problems, producing simple and quadratic equations, with their solutions*, (Cambridge: J. Smith, 1812). 5th edition, 1827.

⁵⁶ Bewick Bridge, *An Elementary Treatise on Algebra* (London: T. Cadell & W. Davies, 1815).

⁵⁷ S. E. De Morgan, *op. cit.*, (18), 7.

⁵⁸ "Augustus De Morgan 1822 Redland": school exercise book containing mathematical notes. University of London Library, MS. 775/330, inside front cover.

which include work on "Cardan's Rule for Solving Cubic Equations",⁵⁹ arithmetical and geometrical progressions, and "A Formula for finding the Root of a Quadratic Cubic or Biquadratic Equation".⁶⁰ By the end of the book, he is studying the summation of infinite series, leading on to the subject of logarithms. His jottings on these topics reveal not only an understanding of advanced mathematical concepts such as the nature of convergency, but also show early evidence of wide reading to a considerably high level; the penultimate page, for example, containing the citation "Vide Preface to Dr Hutton's *Tables*".⁶¹

De Morgan's mathematical abilities were by now visibly manifest. Indeed, so intense was his new-found fascination that it seems to have increasingly distracted him from the mundanities of everyday life. An illustration of this is provided by his wife, concerning the visits by the boys of Parsons' school to St. Michael's Church in Bristol:

Having heard something from Mr. De Morgan of his juvenile delinquencies, arising from thinking more of mathematics than of the scarcely audible sermon, I searched out the school pew during a visit to Bristol, and there found, neatly marked on the oak wainscot partition, the first and second propositions of Euclid and one or two simple equations, with the initials A De M. They were made in rows of small holes, pierced with the sharp point of a shoe-buckle, and are by this time probably repaired and cleaned away.⁶²

But it was not just his interest in mathematics which distracted him from the church sermons. His religious education was also to blame. This had started at an early age with his father. "A rigid Evangelical in tenets and practice - a heritage, doubtless, from his Huguenot ancestry - Colonel De Morgan was known to his fellow officers by the nickname of 'Bible John'".⁶³ His wife shared his beliefs and, after his death, had continued to administer the same discipline. As a child, De Morgan had been taken to church twice in the week, three times on Sunday, and required to give an abstract of every sermon he heard. Not surprisingly, this left him with a lifelong inability to listen to any speaking or lecturing for a prolonged period.

⁵⁹ *ibid*, f.31.

⁶⁰ *ibid*, f.37.

⁶¹ *ibid*, f.39.

⁶² S. E. De Morgan, *op. cit.*, (18), 8.

⁶³ Stirling, *op. cit.*, (26), 24.

The "dreary sermons",⁶⁴ combined with the logical inconsistencies which formed part of the arguments used to convince him, made it inevitable that he would rebel at the first opportunity, though he never became an atheist. While admitting a personal faith in Jesus Christ, he abhorred all forms of hypocrisy or sectarianism and thus refused to join any church, regarding himself throughout life as a "Christian Unattached".⁶⁵ For him, religious belief was a strictly personal experience and nobody else's concern. Moreover, he believed that one should be able to achieve one's goals in life regardless of religious persuasion. As he later wrote in his will, he refrained from any open profession of faith "because in my time such confession has always been the way up in the world".⁶⁶ Such conviction and commitment to principle was to be a constant feature of De Morgan's life.

1.3 Cambridge

The final stage of De Morgan's intellectual development began on 1 February 1823, when he entered Trinity College, Cambridge, at the age of just over sixteen and a half.⁶⁷ This early start to his university career is probably explained by his rapid progress at Parsons' school where, in mathematics at least, he had "soon left his teacher behind".⁶⁸ However, neither Parsons nor De Morgan's mother intended mathematics to be his principal subject of study at Cambridge, the former advising concentration on the classics to comply with the latter's wish that her son should eventually become an Evangelical clergyman. This aspiration would soon be frustrated by two major factors: firstly, De Morgan's insatiable appetite for mathematics; and secondly, the intellectual environment he quickly encountered at Cambridge.

1.3.1 The Tripos

Mathematics had been the dominant subject of study in the University of Cambridge since the early eighteenth century, following the immediate aftermath of the work of Isaac Newton (perhaps the most famous of Trinity College alumni). This period had also seen the origin and evolution of a new method of examining university students for the

⁶⁴ S. E. De Morgan, *op. cit.*, (18), 11.

⁶⁵ Arthur Cowper Ranyard, Obituary notice of Augustus De Morgan, *Monthly Notices of the Royal Astronomical Society*, **32**, (1871-72), 112-118, p.114.

⁶⁶ S. E. De Morgan, *op. cit.*, (18), 368.

⁶⁷ Walter William Rouse Ball & John A. Venn (eds.), *Admissions to Trinity College, Cambridge*, **4**, (London: Macmillan and Co., 1911), 216.

⁶⁸ S. E. De Morgan, *op. cit.*, (18), 4.

conferment of degrees, called the Mathematical Tripos. The name originated in the fifteenth century when, as part of the oral examination prior to receiving their degree, undergraduates would be questioned by an "ould bachilour",⁶⁹ representing the university, who would sit on a three-legged stool, known as a tripos. This name was eventually assumed by the examiner, but over the years its meaning changed many times. By the beginning of the nineteenth century the Tripos had evolved "from a thing of wood to a man, from a man to a speech, from a speech to two sets of verses, from verses to a sheet of coarse foolscap paper, from a paper to a list of names, and from a list of names to a system of examination".⁷⁰

In his *History of the Study of Mathematics at Cambridge*, W. W. Rouse Ball places the origin of the Mathematical Tripos at around 1725, although it does not seem to have been officially recognised by the university until 1750. The examination was initially oral and lasted for one day only, although by 1772 it extended over three days. Subjects examined were "mathematics and a smattering of philosophy".⁷¹ In the early 1770s, examiners began to dictate some of the questions to candidates, requiring written answers in return. By the end of the century this practice had developed into the printing of questions which were distributed as a whole to the candidates. In 1779, the Tripos was extended to four days and to five in 1808. Days one to three concentrated on mathematics, day four on logic, philosophy and religion, and the final day was spent deciding on the order of graduates.

For the candidates, knowing that their entire degree depended on their performance in the Tripos, it must have been a very stressful five days. One of the biggest ordeals, however, was the fact that the examinations were held in January every year in one of the coldest buildings in Cambridge, the senate house (opened in 1730), whose spacious marble floors, while certainly beautiful, were hardly conducive to adequate heating.

Although the examination lasted but a few days it must have been a severe physical trial to any one who was delicate. It was held in winter and in the senate-house. That building was then noted for its draughts and was not warmed in any way; and we are told that upon one occasion the candidates on entering in the morning found the ink frozen at their desks.

⁶⁹ Walter William Rouse Ball, *A History of the Study of Mathematics at Cambridge*, (Cambridge: Cambridge University Press, 1889), 217.

⁷⁰ Christopher Wordsworth, *Scholae Academicae; Some Account of Studies at the English Universities in the Eighteenth Century*, (Cambridge: Deighton, Bell, and Co., 1877), 21.

⁷¹ Rouse Ball, *op. cit.*, (69), 189.

The duration of the examination must have been even more trying than the circumstances under which it was conducted. The hours on Monday and Tuesday were from 8 to 9, 9.30 to 11, 1 to 3, 3.30 to 5, and 7 to 9. ... The examination on Wednesday ended at 11. On Thursday morning at eight a first list was published with all candidates of about equal merit bracketed, and that day was devoted to arranging the men whose names appeared in the same bracket in their proper order. ... The publication of the list was attended with great excitement.⁷²

This is how the Tripos was administered during De Morgan's time at Cambridge. However, a legacy of pre-Tripos days remained, as he later wrote: "All degrees were originally gained by disputations: the substitution of an examination, to see whether the candidates were fit to dispute, is a thing of comparatively modern times."⁷³ The tradition of these disputations dated back to the middle ages and had changed very little in character during the intervening period:

The disputation commenced by the candidate known as the *act* or *respondent* proposing three propositions... on one of which he read a thesis. Against this other students known as *opponents* had then to argue. The discussions were presided over by the moderators..., who moderated the discussion and awarded praise or blame as the case might require.⁷⁴

By the mid-eighteenth century, with the rise of the Tripos as the means of awarding a degree, the importance of the disputation had decreased. Nevertheless, by the university's statutes, every student intending to obtain a bachelor's degree had to undertake at least one disputation during their third undergraduate year. Not surprisingly, since one's performance no longer directly effect one's degree result, the quality of the arguments soon declined. By the early nineteenth century, these contests seem to have degenerated into farce, as William Whewell (see below) wrote in 1819:

They are held between undergraduates in pulpits on opposite sides of the room, in Latin and in a syllogistic form. As we are no longer here in the way either of talking Latin habitually or of reading logic, neither one nor the other is very scientifically exhibited. The syllogisms are such as would make Aristotle stare, and the Latin would make every classical hair in your head stand on end. Still it is an exercise well adapted to try the clearness

⁷² *ibid*, 192-193.

⁷³ Augustus De Morgan, Wrangler, *Penny Cyclopædia*, **27**, (London: Charles Knight and Co., 1843), 580.

⁷⁴ Rouse Ball, *op. cit.*, (69), 165.

and soundness of the mathematical ideas of the men, though they are of course embarrassed by talking in an unknown tongue.⁷⁵

The situation may seem comical today, but for the undergraduates of the 1820s it was still a serious matter. The rigid Aristotelian structure of the arguments and the antiquated language required for its delivery demanded a considerable amount of proficiency in both subjects, regardless of the fact that neither would be needed for the subsequent Tripos examination. The necessity for adequate preparation was reinforced by the need for the student to defend his thesis, in the appropriate form, from any possible objection. De Morgan's disputation took place in 1826 and was, by all accounts, a gruelling affair:

I was badgered for two hours with arguments given and answered in Latin, - or what we called Latin - against Newton's first section, Lagrange's derived functions, and Locke on innate principles. And though I *took off* everything, and was pronounced by the moderator to have disputed *magno honore*, I never had such a strain of thought in my life.⁷⁶

The results of these disputations determined those who were deemed fit to receive degrees, or at least sit for the Tripos. Based on their oral performance, men were arranged into four tentative groupings, corresponding to their expected class of degree. The lowest group were known as *poll men* who, while awarded a degree, did not receive honours. Above them were the *junior* and *senior optimes*. Those who achieved first class status were called *wranglers*, from the word meaning to dispute. "Of these the first in merit is the *Senior Wrangler*: but persons not accustomed to the phraseology of the University are apt to confound Wrangler with Senior Wrangler, that is, to imagine that any one of their friends who may have obtained a wranglership must necessarily be the first man of his year."⁷⁷ The much coveted position of senior wrangler was decided at the senate house examinations each January along with the precise ordering of the other candidates within their assigned groups. Disputations were finally abolished in 1839.⁷⁸

It was into this dauntingly competitive academic world that the young De Morgan entered in 1823. Although he had been one of Parsons' most outstanding pupils, in his new environment he was little more than a promising schoolboy. However, by the time of

⁷⁵ Isaac Todhunter, *William Whewell...An Account of his Writings*, vol. 2, (London: Macmillan and Co., 1876), 35-36.

⁷⁶ Augustus De Morgan, *A Budget of Paradoxes*, (London: Longmans, Green, and Co., 1872), 305.

⁷⁷ De Morgan, *op. cit.*, (73).

⁷⁸ James W. L. Glaisher, The Mathematical Tripos, *Proceedings of the London Mathematical Society*, (1), **18**, (1886-87), 4-38, p.12.

his graduation four years later, he had blossomed into a mature mathematician, well versed in all areas of his subject and capable of undertaking original research. While it is certainly not surprising that someone of the intellectual and mathematical capability of Augustus De Morgan achieved his academic potential, this accomplishment does raise certain questions about the tuition received and course of study undertaken by him while an undergraduate at Cambridge. Thus, in order to consider the final development of De Morgan's mathematical powers, it is first necessary to give details of the men who were active in promoting this development: his college tutors.

1.3.2 The Tutors

As a student at Cambridge, De Morgan received tuition, in the form of lectures and personal tutorials, from seven men. All were exceptionally capable mathematicians in the early stages of a university career, being in their twenties or early thirties. All but one were clergymen, having taken or intending to take, holy orders. Of these seven men, three were already well known in academic circles by 1823. Their fame would later increase as their interests diversified, with the effect that they are still familiar to historians of science today. The remaining four are more obscure, but no less consequential to this study; indeed, one in particular will later play a vital role in the furtherment of De Morgan's mathematical career. We will begin, however, with an introduction to the most prestigious of his teachers.

George Peacock (1791-1858) is best remembered today for his contributions to the development of abstract algebra in the early nineteenth century, contained in his *Treatise on Algebra* (1830, 1842).⁷⁹ However, in De Morgan's undergraduate days, his fame rested on his work as a co-founder of the short-lived but influential Analytical Society in 1812.⁸⁰ This had come about through the efforts of himself and two fellow undergraduates, Charles Babbage (1792-1871) and John Herschel (1792-1871), with the intention of introducing Lagrange's analytical methods of differential and integral calculus, currently employed on the Continent, into the Cambridge syllabus, thus replacing the Newtonian geometrically-based methodology with its fluxional 'dot' notation which had been entrenched in Britain for well over a century.

⁷⁹ Charles C. Gillispie (ed.), *Dictionary of Scientific Biography*, (hereafter cited as 'D.S.B.') **10**, (New York: Scribner's, 1970), 437-438.

⁸⁰ Philip C. Enros, The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics, *Historia Mathematica*, **10**, (1983), 24-47.

To this end the three men had published a translation of a calculus textbook by the Frenchman Silvestre Lacroix in 1816. The following year, Peacock had used his position as one of the Tripos moderators to introduce the continental notation into the papers set. His return to the post in 1819 and 1821 had ensured that by the early 1820s the new symbolism was well-established within the university, although fluxional methods were still taught and examined for some years by lecturers opposed to the analytical approach. To consolidate this success, as well as to provide students with a guide to the new methods, Peacock published *A Collection of Examples of the application of the Differential and Integral Calculus* in 1820. In 1823, the year of De Morgan's entrance, he was made a tutor at Trinity College, where, by all accounts, he was highly regarded by his students:

While his extensive knowledge and perspicuity as a lecturer maintained the high reputation of his college, and commanded the attention and admiration of his pupils, he succeeded to an extraordinary degree in winning their personal attachment by the uniform kindness of his temper and disposition, the practical good sense of his advice and admonitions, and the absence of all moroseness, austerity, or needless interference with their conduct.⁸¹

Amongst those slightly less active, but still instrumental, in promoting the use of the new calculus were William Whewell (1794-1866) and George Biddell Airy (1801-1892). Like Peacock, Whewell had been the second wrangler of his year. He was also appointed a tutor at Trinity at the same time, although he had been an assistant tutor for five previous years.⁸² His *Elementary Treatise on Mechanics* (1819), which introduced French analytical methods into the subject, had been followed in 1820 by his endorsement of the new notation when he became a Tripos moderator. Three years later, *A Treatise on Dynamics* further contributed to increasing awareness of the continental processes among Cambridge students. But mathematics was far from being Whewell's sole intellectual pursuit. Abundant works on philosophy, theology, political economy, architecture, mineralogy and education soon ensured his position as one of the most influential and highly regarded figures in the British scientific community.⁸³

⁸¹ Rouse Ball, *op. cit.*, (69), 124.

⁸² John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 6, 425.

⁸³ *D.S.B.*, 14, 292-295.

Airy was the youngest of all of De Morgan's college tutors. One of Peacock's first (and finest) pupils, he gained his B.A. a mere month before De Morgan's arrival in Cambridge, having achieved the position of Senior Wrangler with ease. A college fellowship (almost a formality), to which he proceeded the following year, was held together with a tutorship until 1826.⁸⁴ His tuition during these two years, of which De Morgan was a recipient, further extended the range of topics which were now treated by continental methods and resulted in the publication of *Mathematical Tracts on Physical Astronomy, the Figure of the Earth, Precession and Nutation, and the Calculus of Variations* (1826), by far the most influential work on mathematical physics at Cambridge for many years. His election to the Lucasian Chair of Mathematics in 1826 was the first of several prestigious scientific appointments held during his long career.⁸⁵

The academic stature of these three tutors was already high in 1823, and had increased considerably by De Morgan's graduation four years later. However, the reputation of his other four teachers, while not insubstantial at the time, would never achieve that of their eminent colleagues, although this is principally due to their later neglect of mathematics in favour of more spiritual matters. Henry Parr Hamilton (1794-1880), for example, was the author of two textbooks of some importance. The first, *Principles of Analytical Geometry* (1826), fulfilled the long-standing need for a textbook on that subject, serving as "an improvement on anything then accessible to English readers".⁸⁶ Two years later, in 1828, his more elementary *Analytical System of Conic Sections* "defined the curves by the focus and directrix property, as had been first suggested by Boscovich".⁸⁷ This work reached a fifth edition in 1843. Yet his success as an author does not appear to have satisfied him. He left Trinity College in 1830 for a career in the church, serving as Dean of Salisbury from 1850 until the end of his life.⁸⁸

Henry Coddington (c.1799-1845) was another promising mathematician who never quite achieved his full potential. Senior Wrangler in 1820, he was a college tutor from 1822 to 1833, as well as being a "good linguist and an excellent musician".⁸⁹ His main work was *An Elementary Treatise on Optics* (1823), a geometrical treatment which was apparently

⁸⁴ Venn, *op. cit.*, (82), 1, 21.

⁸⁵ *D.S.B.*, 1, 84-87.

⁸⁶ Rouse Ball, *op. cit.*, (69), 122.

⁸⁷ *ibid*, 129.

⁸⁸ Venn, *op. cit.*, (82), 3, 214.

⁸⁹ *ibid*, 2, 83.

"practically a transcript of Whewell's lectures in Trinity on the subject".⁹⁰ He too joined the church, being ordained as a deacon in 1823 and a priest in 1826.⁹¹ Another tutor, Thomas Thorp (1797-1877) also eventually abandoned an academic career for a religious one, going on to become Archdeacon of Bristol from 1836 to 1873.⁹²

De Morgan's principal tutor for the full four years of his Cambridge residence was John Philips Higman (1793-1855). Higman had entered Trinity College in 1812, becoming first a member and then the secretary of the Analytical Society through his friendship with Charles Babbage.⁹³ He graduated as third wrangler in 1816, the year in which Whewell was second.⁹⁴ In 1822, a year after taking holy orders, he was appointed to a college tutorship, which he was to hold for twelve years before spending the rest of his life as rector of Fakenham in Norfolk.⁹⁵ His sole published mathematical work was *A Syllabus of the Differential and Integral Calculus* (1826) which, although sound enough, contained nothing of great originality.

Although it was Higman with whom De Morgan was to have the most contact as an undergraduate, all of his college tutors were to exercise considerable influence on his later academic life to some extent. Most particularly, it is highly probable that he acquired his later interest in algebra from Peacock and his love of astronomy from Airy. It is also entirely conceivable that his passion for the history of science was inspired (and certainly encouraged) by Peacock and Whewell, both of whom had strong interests in that area.⁹⁶ There is also a suggestion that it was from Whewell that De Morgan inherited his great fascination for logic,⁹⁷ although the link is less obvious. However, the fundamental contribution of all of these tutors was to confirm De Morgan's intention to concentrate on the study of mathematics while at college, and ultimately to determine the course of his professional career. Before we can proceed to a consideration of this eventual occupation

⁹⁰ Rouse Ball, *op. cit.*, (69), 131.

⁹¹ He died on 3 March 1845 in Rome while travelling, not entirely successfully, for health reasons. - *Gentleman's Magazine*, **24**, (1845), 90.

⁹² Venn, *op. cit.*, (82), **6**, 182.

⁹³ Enros, *op. cit.*, (80), 33.

⁹⁴ Venn, *op. cit.*, (82), **3**, 364.

⁹⁵ He died on 7 August 1855. - *Gentleman's Magazine*, **44**, (1855), 329.

⁹⁶ Peacock's article 'Arithmetic' in the *Encyclopaedia Metropolitana* (Vol. I., 369-523), written in 1825, was the best historical account of the subject to date; Whewell was later famous for, amongst many other things, his three-volume *History of the Inductive Sciences*, first published in 1837.

⁹⁷ Alexander MacFarlane, *Lectures on Ten British Mathematicians of the Nineteenth Century*, (London: Chapman & Hall, 1916), 20.

(with which this thesis is largely concerned), we must give some account of De Morgan's undergraduate studies, beginning with his arrival at Trinity in February 1823.

1.3.3 The Student

He entered the College in what was then called a "by-term", i.e. not at the beginning of the academic year. This, plus his early age, would certainly have put him very much at an initial disadvantage compared to the rest of his year since he had missed half of that session's tuition. Also, since his initial college reading obliged him to concentrate on classics to a greater extent than he would have liked, it is scarcely surprising that at his first examination he gained no higher position than top of the second class. However, although this result was disappointing, to attain such a standing was certainly an achievement, particularly when it is remembered that he had been at Cambridge for only three months.

Real progress began to be made during his second year, when more mathematical study was required than the first. College lectures inspired him to enlarge his own capacity for the subject and, under the growing influence of his accomplished tutors, he immersed himself in mathematical literature, devoting himself to its study and absorbing far more information than was required by the syllabus. We must remember that this stimulus would have been all the more profound to a young man who had never before experienced the teaching of such talented mathematicians. As his wife later wrote, "It was like new life to him when he listened to Dr. Peacock's explanations, and followed up the study he loved under the guidance of one who knew how to show the way."⁹⁸ This increased activity soon produced tangible results, revealed in a letter from John Higman to De Morgan's mother at the close of his second year:

Notwithstanding my disappointment last year, I had formed such a very favourable opinion of Mr. De Morgan's talent, and was so much pleased with his industry and the implicit attention he paid to every direction that I gave him, that I felt perfectly assured that he would, on the next trial, when less depended on Classics, distinguish himself in a very extraordinary manner. Nor have my prognostics with regard to his success proved deceitful; he is not only in our first class, but far, very far, the first in it.⁹⁹

Thus far, the voraciousness of De Morgan's mathematical study, both as a schoolboy and an undergraduate, has been amply described. However, while we have shown that his

⁹⁸ S. E. De Morgan, *op. cit.*, (18), 12.

⁹⁹ *ibid.*

reading *was* extensive, we have not yet seen *what* works he actually read. The reason for this is that no comprehensive undergraduate reading list existed, since students were individually advised on their reading by tutors, subject to their particular strengths and weaknesses, not to mention their own interests. Their progress, and ultimately their degree result, thus largely depended on their ability to master enough material prior to taking the Tripos examination, through reading the recommended books.

Some idea of the reading in vogue during the early nineteenth century may be gleaned from the reminiscences of Sir Frederick Pollock (1783-1870), who replied to De Morgan's queries on this point in the summer of 1869. Pollock had been a student at Trinity College twenty years earlier than his correspondent, being the Senior Wrangler of 1806.¹⁰⁰ Indeed, he claimed to be "the last *geometrical* and *fluxional* senior wrangler",¹⁰¹ although that is unlikely. What is certain is that the requirements for a senior wranglership in his day do not seem particularly high, since his first year's reading was composed solely of Robert Simson's 1756 edition of Euclid's *Elements*, James Wood's *Elements of Algebra* (1806) and John Bonnycastle's *Introduction to Algebra* (1782) - and in neither of the last two books did he initially read further than quadratic equations.

Pollock's later reading included the higher parts of Wood's *Algebra*, largely comprising the theory of equations, Samuel Vince's *Principles of Fluxions* (1798) and a good deal of Newton's *Principia*. In addition to this printed material, there were also "certain MSS floating about which I copied"¹⁰² to derive information on other subjects such as conic sections and mechanics. By his own admission, Pollock's reading was minimal and his mathematical knowledge was not particularly profound or wide-ranging; however, he said, "my *forte* was, that what I *did* know I *could produce at any moment* with PERFECT *accuracy*".¹⁰³ Hence it is not difficult to see that the Tripos system tended to favour those with the ability to reproduce mathematical theory from memory at the expense of those who craved a more comprehensive view of the subject.

De Morgan fell into this latter category: his thirst for mathematical knowledge was unquenchable. One reason for this vast appetite was the highly advanced state of his education in the subject by the time he reached university. We have already seen that his

¹⁰⁰ Venn, *op. cit.*, (82), 5, 150.

¹⁰¹ S. E. De Morgan, *op. cit.*, (18), 388.

¹⁰² *ibid*, 387.

¹⁰³ *ibid*, 388.

mathematical erudition on entering Trinity extended further than Pollock's first-year reading. (Indeed, Pollock's mathematics on his arrival in 1802 had consisted merely of "a knowledge of Euclid and algebra to quadratic equations, nothing more".¹⁰⁴) Furthermore, De Morgan's natural ability and almost effortless progress resulted in an early concentration on topics which were among the most abstruse subjects offered at Cambridge at that time.

It is with some certainty that we can make this claim since seventeen mathematical notebooks from his Cambridge days still survive. They obviously include no more than a fraction of the material undertaken by him during this time, but they still provide an invaluable, and possibly unique, source for determining at least part of his course of undergraduate study. Of these books, eight are concerned with various sections of the *Principia* and its applications, with six involving different aspects of the calculus, one on conic sections, one on geometry and one on spherical trigonometry and astronomy. That these were high-powered topics of undergraduate study is not contentious: what remains to be shown is how soon De Morgan came to study them.

The majority of the notebooks are undated, which makes it difficult to know exactly when they come from - if indeed they come from a single period. However, three books do have dates inscribed, in De Morgan's handwriting, on their covers: September 1824, October 1824, and February 1825. Furthermore, the topics covered in some of the undated books can be seen to precede or follow on from material covered in the dated manuscripts. However, this still does not provide conclusive evidence that they were all written within the same six month period as some of the other manuscripts were obviously started at a later time. On this evidence, based on the high level of the subjects treated, plus only three dated notebooks, we can be no more precise than to conclude that they date from around the summer of 1824 to the end of 1826.

If we begin with the earliest dated document, from September 1824, we find that after only eighteen months at Cambridge he was already familiar with parts of Newton's *Principia*, the notebook from this date being entitled "Principia. Vol I. Section 10th and 11th".¹⁰⁵ His study of Newton must therefore precede the autumn of 1824, since he obviously spent some time on the earlier sections. This is corroborated by other undated

¹⁰⁴ *ibid.*

¹⁰⁵ "Principia. Vol I. Section 10th and 11th. September 1824": college notebook. University of London Library, (hereafter cited as 'ULL'), MS. 775/338, front cover.

notebooks dealing with Sections 6, 7 and 8 plus "Deductions from The 7th and 8th Sections".¹⁰⁶ Such applications included comparisons of centrifugal and centripetal forces at the equator and an interesting hypothetical problem involving the moon: "Suppose the moon deprived of her angular velocity to fall towards the earth. To find the time of her descent."¹⁰⁷

As to where De Morgan acquired his Newtonian theory, we can be sure that it was not solely from the pages of the *Principia*. Even potential wranglers were not expected to grapple with the complexity of Newton's work in its undiluted form. As to which commentary he used, the only clue lies in a small reference in one of his notebooks to "Carr's Newton p.159".¹⁰⁸ This is an edition of the first three sections by the Rev. John Carr, published in 1824; so De Morgan was obviously keeping up to date with recent publications. Other than this, personal tutorials with John Philips Higman seem to have been another source of information on mechanical matters: in one of his books, a general investigation of an orbit under the inverse-square law is followed by "Another Method by Rev^d. J. P. H."¹⁰⁹

His study of astronomy began with the necessary reading of spherical trigonometry, before proceeding to applications such as computing the effects of refraction, aberration, and finding "the time of sunrise in a given latitude on a given day".¹¹⁰ The single notebook in which this material is contained is particularly conspicuous in that it lists the four principal books used for this subject on its back cover: John Playfair's two-volume *Outlines of Natural Philosophy* (1812-14), Robert Woodhouse's *Elementary Treatise on Astronomy* (1812), John Brinkley's *Elements of Astronomy* (1813) and Samuel Vince's *Principles of Astronomy* (1799). This notebook is the only one in which De Morgan is explicit about his reading.

As far as his reading for the calculus was concerned, only one book is ever cited: Peacock's *Collection of Examples* from 1820. However, this is referred to with such regularity¹¹¹ that, if it was not the only book used, it would certainly seem to have been

¹⁰⁶ "Section 8th and Deductions from the 7th and 8th Sections": college notebook. ULL, MS. 775/335, f.13.

¹⁰⁷ "Section 6th and 7th": college notebook. ULL, MS. 775/334, f.27.

¹⁰⁸ *ibid*, f.43.

¹⁰⁹ *op. cit.*, (105), f.15.

¹¹⁰ "Astronomy", ULL, MS. 775/342, f.14.

¹¹¹ "Differential Calculus", ULL, MS. 775/332, f.51, f.61; "Integral Calculus", ULL, MS. 775/343, f.9, f.12, f.15, f.18.

the main one. Despite the prevalence of the new methods at Cambridge following the success of the Analytical Society, De Morgan's instruction in the calculus was not totally analytical. The first page of his notebook on the differential calculus notes that there were "Different Systems pursued - Leibnitz used infinitesimals of descending orders. Newton used the Principles of Limits or Fluxions. Lagrange rejecting both infinitesimals and Limits has used a method purely Algebraical."¹¹²

It then proceeds with miscellaneous definitions and examples of various applications such as finding subtangents or areas under curves, first using infinitesimals, then the method of limits. No statement is made with respect to foundational issues: both methods seem to be taken as equally valid. The usual topics are treated as his reading progresses: differentiation of functions, higher derivatives, Taylor's and Maclaurin's Theorems, maxima and minima, tangents and normals, and points of inflection. However, it is not long before his reading becomes more advanced, with considerations of cycloidal, spiral and polar curves being followed by several proofs of Lagrange's Theorem, including one direct from the *Théorie de Fonctions Analytiques* (1797).

By October 1824, De Morgan was studying differential equations, both ordinary and partial, but no hints with regard to reading are given. The same is true for his notebook on the calculus of finite differences, to which he had progressed by February 1825. However, the work most likely to have been followed in Cambridge at this time would have been John Herschel's book on the subject published five years previously.¹¹³ With a mastery of such advanced topics after only two years at university, it is not surprising that he remained high in his class throughout 1825, being awarded a Trinity scholarship in April. Having progressed as far in two years as many typical students would in their university career, De Morgan was still only just over half-way through his course of study. Yet his reading remained as voracious as ever, extending far beyond the requirements of his college tutors.

He was by nature a compulsive reader on almost any topic and, when not consuming mathematical books, would devote his leisure hours to the study of works on philosophy, metaphysics, theology, literature and history. Towards the end of his life he wrote to a friend: "I did with Trinity College library what I afterwards did with my own - I foraged

¹¹² "Differential Calculus", ULL, MS. 775/332, f.1.

¹¹³ John Herschel, *A Collection of Examples of the Applications of the Calculus of Finite Differences*, (Cambridge: J. Deighton and Sons, 1820).

for relaxation."¹¹⁴ A result of this discursive reading was the development of an almost encyclopaedic knowledge of an impressive range of scientific subjects. His wife recalled, for example, that as early as their meeting in 1827, he was already expert on antiquarian science, being "well informed in Eastern astronomy and mythology" and critical of writers on the subject, pointing out "the insufficiency of their theories to account for all that they have tried to explain".¹¹⁵

His literary digressions were not always of an academic nature, since he had an "insatiable appetite for novel reading, always a great relaxation in his leisure time, and doubtless a useful rest to an over-active brain in the case of one who did not care for riding or boating. Let it be good or bad from a literary point of view, almost any work of fiction was welcome, provided it had plenty of incident and dialogue, and was not over-sentimental.... He soon exhausted the stores of the circulating library in Cambridge."¹¹⁶ As he later recalled: "I read an enormous deal of fiction - all I could get hold of - so my amusement was not all philosophical."¹¹⁷ His distinctive characteristic of "reading through a great part of the night, and, in consequence, getting up very late the next day, was notorious; and fellow-collegians, coming home from a wine party at four in the morning, might find him just going to bed".¹¹⁸

However, if one were to rely exclusively on Sophia De Morgan's account of her husband's college life, he would emerge as a paragon of scholastic virtue with no time for anything except books. But this is not the full picture. A tantalising glimpse of the less serious side to his nature is given in a letter to Sir William Rowan Hamilton over three decades later:

When I was an undergraduate, it happened to me to get very jolly in company with a party who were celebrating the new scholarship of our host. Being, as aforesaid, merry, we proceeded to sing; when it struck one of our party that we could sing as well as the choristers, a notion which came of punch and not of reason. To test the point we all got our surplices, and stood round the table, when a question arose as to what we should chant. Some one proposed $PV.VG : QV^2 : : CP^2 : DC^2$, which met with approbation. We tried to make it fit all manner of tunes; I remember "Zitti Zitti," "the Evening Hymn," and "The Campbells are coming." But

¹¹⁴ S. E. De Morgan, *op. cit.*, (18), 393.

¹¹⁵ *ibid*, 21.

¹¹⁶ Stirling, *op. cit.*, (26), 26.

¹¹⁷ S. E. De Morgan, *op. cit.*, (18), 393.

¹¹⁸ *ibid*, 16.

we left off with a notion that Newton was not so easily set to music as we thought.¹¹⁹

His musical talents found slightly less raucous employment through his membership of the 'Camus', or Cambridge Amateur Musical Union Society, where his "exquisite" flute-playing apparently earned him a reputation as "one of the best amateur players in England".¹²⁰

In January 1827, he sat the Tripos examination, following his disputation of the previous year which had resulted in his being bracketed as a prospective wrangler. His confidence was no doubt also boosted by the widespread expectation that he would be the senior or second wrangler of his year. However, when the results were announced, it was revealed that he had achieved the position of only fourth wrangler, a place which, as it was later said, "failed to declare his real power or the exceptional aptitude of his mind for mathematical study".¹²¹ Ironically, it was his exhaustive programme of reading which was principally to blame for this disappointing result, since it often distracted him from the course required for examination.¹²² The realisation that wide and discursive mathematical study had actually been *detrimental* to his performance imbued a thorough distrust of competitive examinations which was to last for the rest of his life.

It may be of interest to briefly note the three men who stood above De Morgan in the Tripos of 1827, none of whom went on to achieve further mathematical distinction. Senior Wrangler of that year was Henry Percy Gordon (1806-1876) of Peterhouse. A year after leaving Cambridge, he entered Lincoln's Inn to study law, being called to the Bar three years later. He succeeded to the title of Laird of Knockespock in Scotland in 1854.¹²³ Below him was Thomas Turner (1804-1883) of Trinity College. He too studied law at Lincoln's Inn, qualifying as an equity draftsman and conveyancer.¹²⁴ The third wrangler, Anthony Cleasby (1804-1879) of Trinity College, entered the Inner Temple immediately after the Tripos of 1827. The most successful of the three lawyers, he became a Q.C. in 1861 and was knighted in 1868.¹²⁵

¹¹⁹ Graves, *op. cit.*, (39), 546.

¹²⁰ Ranyard, *op. cit.*, (65), 113.

¹²¹ *ibid*, 113-114.

¹²² An example of this extra-curricular mathematical reading occurs in the form of one of his college notebooks (ULL, MS. 775/346) which contains lengthy "Extracts from Lagranges Théorie des Fonctions and Leçons sur Le Calcul des Fonctions" translated into English.

¹²³ Venn, *op. cit.*, (82), 3, 91.

¹²⁴ *ibid*, 6, 253.

¹²⁵ *ibid*, 2, 63.

De Morgan now had to decide on a profession, since "few, if any, occupations in England in the early 19th century required much training in mathematics or involved mathematics at all".¹²⁶ His degree result was more than sufficient to win him a college fellowship if he so wished. However, it was first necessary to pass a theological test (not abolished at Oxford and Cambridge until 1871) to which, due to his religious convictions, he would not subscribe.¹²⁷ An academic career thus closed to him and his ordination being out of the question, he was offered a cadetship in the army, but his mother vetoed the idea on the grounds of his optical disability. The only other real option was the Bar, although he toyed with the idea of a medical career. Eventually, however, he followed his three fellow wranglers and entered Lincoln's Inn to study law.

¹²⁶ Enros, *op. cit.*, (80), 41.

¹²⁷ It is worth mentioning that De Morgan's doctrinal scruples, strong though they undoubtedly were, did not prevent him actually taking his B.A. degree, which required acceptance of the thirty-nine Articles of Faith. It can only be assumed that he took the oath under (silent) protest.

Chapter 2

From Appointment to Disappointment, 1828-1831

2.1 Appointment

2.1.1 The Formation of London University

De Morgan's final Cambridge years coincided with the genesis of a movement to found a university in London, the only capital city in Europe without such an institution at this time. Indeed, up to this period, no university had been founded in England since Oxford and Cambridge in the Middle Ages, and, since these universities were so guarded by religious tests, people such as Jews or Dissenters from the Church of England were effectively barred from higher education. So too were the growing urban middle classes who, while not poor, were nevertheless incapable of financially supporting their offspring through courses of study away from home.

In order to rectify this situation, certain liberal-minded men, influenced partly by the Scottish universities and partly by the writings of Jeremy Bentham (1748-1832), came to favour the establishment of a secular institution in London. In a letter to the Whig M.P. Henry Brougham (1778-1868), published in *The Times* in February 1825, the poet Thomas Campbell (1777-1844) proposed setting up "a great London University....for effectively and multifariously teaching, examining, exercising, and rewarding with honours in the liberal arts and sciences, the youth of our middling rich people, between the age of 15 or 16 and 20".¹ This was the first step in the creation of an educational institution "which would comprehend all the leading advantages of the two great universities, together with the domestic supervision of the parents, and at a rate of expense so economical as to bring the benefits of the establishment within the reach of almost every class in society".²

In the months following the proposal's publication, the movement quickly gained momentum, enlisting the support of Jewish financier Isaac Goldsmid (1778-1859), mathematician Olinthus Gregory (1774-1841), Scottish educational reformer George Birkbeck (1776-1841), and many leading liberals of the day including Sir James Mackintosh (1765-1832), Joseph Hume (1777-1855), Henry Warburton (1784-1858),

¹ *The Times*, 9 Feb. 1825, 4a.

² *ibid*, 6 June 1825, 4a.

James Mill (1773-1836), George Grote (1794-1871), Zachary Macaulay (1768-1838), and Lord John Russell (1792-1878). A prospectus was issued in July 1825, announcing that the project would be financed by the issue of shares and voluntary contributions, each holder of a hundred pound share being entitled to send one student to the university at a concessionary rate. It was also stated that "the emoluments of the Professors will be made to depend on the fees received from students, with the addition of very moderate salaries".³

One year after its first suggestion, on 11 February 1826, the London University was officially founded with the signing of the Deed of Settlement by the twenty-four members of the first Council.⁴ This had been appointed two months previously⁵ along with an Education Committee⁶ whose function, initially at least, was to interview and select the university's teaching staff. Membership of this ten-man committee was divided between intellectuals (Birkbeck, Campbell, Gregory, Grote and Mill), politicians (Viscount Dudley & Ward and the Marquis of Lansdowne) and those who could be described as both (Brougham, Mackintosh and Warburton). Three of these men deserve special attention.

Gregory had been professor of mathematics at the Royal Military Academy in Woolwich for twenty years. A skilled mathematician and engineer, in addition to editing the *Gentleman's* and *Ladies' Diaries* at different periods, he was also the author of several mathematical textbooks.⁷ Brougham, though best known for his high-profile career as a politician and lawyer, was a competent amateur mathematician and scientist, having published papers on mathematical and physical subjects in the *Philosophical Transactions of the Royal Society* during the 1790s.⁸ Finally, Warburton, whilst also better remembered for his politics, had achieved a reputation as a "scholar and man of science", graduating from Trinity College Cambridge as twelfth wrangler in 1806.⁹ These three committee-members, being the most mathematically erudite, were to play the greatest part in the eventual selection of the new university's first professor of mathematics.

³ *Prospectus of the London University*, (London: Richard Taylor, 1825), 2; *The Times*, 9 July 1825, 2d.

⁴ Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 29.

⁵ Council Minutes, vol. I, ff.1-2.

⁶ *ibid*, f.3.

⁷ *Dictionary of National Biography*, 23, 103.

⁸ *D.N.B.*, 6, 448-58.

⁹ *D.N.B.*, 59, 296-7.

Around Christmas 1826 adverts appeared in various newspapers, such as the *Morning Chronicle*, *The Times* and *The Globe*, advertising vacancies for twenty-four professorships ranging from Greek to chemistry, political economy to surgery. Two mathematical chairs were offered: "Elementary Mathematics" and "Higher Mathematics and Mathematical Physics".¹⁰ Applications were not slow to arrive. As early as the summer of 1825, it had been reported that "the new professorships are understood to be already in great request as the respectability of the employment is unquestionable, and its situation in London, the centre of all attraction, both for business and popularity, as well as the profits certain to be derived from crowded classes, contribute to make it highly desirable".¹¹

So began the lengthy process of appointing professors. The first decisions were announced in July 1827, with further appointments made later in the year. The election to the mathematical chair was to prove particularly long and complex, involving much indecision, prevarication and uncertainty. However, recent research undertaken primarily in the University College archives, the University of London Library, the British Library and the Royal Society has provided the historian with hitherto apparently unknown documents which reveal much more about the selection process than was previously known. It is with the aid of these manuscripts that we can now attempt to piece together a more complete picture of the competition, starting with the applicants themselves.

2.1.2 The Applicants

So confused are the records that even the number of candidates is uncertain. For example, in his history of the college, H. Hale Bellot gives the figure as twenty,¹² while as far as De Morgan's wife is concerned, it is thirty-two.¹³ De Morgan himself, not normally prone to exaggeration, further adds to the confusion by putting the number as high as fifty!¹⁴ It is known that Bellot relied for his information on the handwritten council minutes kept in the college archives; yet they give the names of *twenty-two* candidates, two of which, we can only assume, must have somehow escaped his notice. It is also thought that he never saw the actual letters of application which can now be found in the

¹⁰ Council Minutes, vol. I, Appendix 18, ff.34-35.

¹¹ *The Times*, 21 July 1825, 2e.

¹² Bellot, *op. cit.*, (4), 41.

¹³ Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, and Co., 1882), 24.

¹⁴ *ibid*, 312; Royal Society Herschel Papers, MS.HS 6.358, De Morgan to John Herschel, 9 Aug. 1862.

Table 1
Candidates for the Mathematical Chairs - 1827/8.

CANDIDATE	AGE	DATE OF APPLICATION	DATE OF RECEIPT IN MINUTES	POST
John Walker	59	30 October 1826	-----	Elementary
Charles Slee	?	17 January 1827	20 January 1827	"
Thomas Collins	31	23 January 1827	3 February 1827	"
Peter Nicholson	62	26 January 1827	3 February 1827	"
Thomas Lyell	?	1 February 1827	-----	"
Edward Drury Butts	30	9 February 1827	10 February 1827	"
Robert T. Ambler	?	23 March 1827	24 March 1827	"
George G. Carey	?	3 April 1827	9 April 1827	"
John Herapath	37	25 April 1827	28 April 1827	Either
Dionysius Lardner	34	28 April 1827	28 April 1827	"
J.A. Dotchin	?	30 April 1827	5 May 1827	Elementary
Henry Moseley	26	11 May 1827	12 May 1827	Higher
William Jennings	?	19 May 1827	-----	Elementary
William S. Sankey	?	22 May 1827	5 November 1827	"
A. Levy	31	31 May 1827	-----	Either
John Radford Young	28	31 May 1827	-----	Elementary
Andrew Bell	30s	27 June 1827	5 November 1827	"
William Ritchie	37	28 July 1827	5 November 1827	"
James Angus	25+	31 July 1827	5 November 1827	Either
Thomas G. Hall	24	Summer 1827	5 November 1827	"
Thomas Hewitt Key	28	Summer 1827	5 November 1827	"
Mr. Ward	?	Summer 1827	5 November 1827	"
Robert Wallace	?	8 September 1827	5 November 1827	"
W. Shires	50s	24 October 1827	-----	"
Patrick Corcoran	?	30 October 1827	5 November 1827	Elementary
Augustus De Morgan	21	22 December 1827	22 December 1827	Either
Charles John Myers	26	3 January 1828	5 January 1828	"
Richard Abbatt	27	4 January 1828	-----	Elementary
Frederick Leicester	35+	11 January 1828	12 January 1828	Either
Jean G. R. de Joux	35+	15 January 1828	-----	Higher
Joseph H. Harris	25-30	11 February 1828	-----	Either

college manuscripts archive. While not entirely complete, this collection includes letters of introduction and enquiry from twenty-nine individuals. However, for two of the candidates listed in the minutes, no letters survive. We can thus be fairly certain that at least thirty-one people applied for the post of mathematics professor at the new London University between January 1827 and February 1828, making Sophia De Morgan's account the most accurate and relegating her husband's to little more than a whimsical boast!

Three features are worth stressing. Firstly, the fact that nearly a third of the applications extant in the archives today do not seem to have had any official recognition from the college. As late as May 1830, John Walker, the very first applicant, was writing to request the return of testimonials sent in more than two years previously, remarking that "my letter of application I have reason to believe never came before the Council, tho' it was sent in to the Office appointed in their advertisement".¹⁵ However, while this may go some way towards explaining the aforementioned discrepancies between various accounts of the competition, there does not appear to be any similar explanation for the oversight itself. Secondly, while applications arrived at a fairly constant rate throughout 1827 - with the majority being recorded in the council minutes - those from mid-May to October remained unacknowledged until November. No definite explanation can be given here either, although it will be seen that between these months, the council temporarily lost interest in the matter, deferring a decision until 'better' candidates presented themselves.

Finally, one is struck by the relative youth of the applicants. Of the twenty-one candidates whose ages we can ascertain, no less than eighteen were under 40, with the average applicant being in his early 30's. At 62, Peter Nicholson was very probably the oldest, while De Morgan was the youngest at only 21. Most contenders were English, eleven of whom resided in or around London. Eight were Cambridge men. Of the remainder, Angus, Bell, Lyell, Ritchie, Sankey, Slee and Wallace were Scottish; Corcoran, Lardner and Walker, Irish; and de Joux and Levy, French. The vast majority of names are unfamiliar, both to the mathematician and the historian, most of the applicants going on to achieve obscurity elsewhere, and only eight warranting an entry in the *Dictionary of National Biography*. Few letters of application give any real clues as to reasons for their eventual rejection; Walker's was perhaps too early, Harris's definitely too late. However,

¹⁵ UCL College Correspondence (Applications), John Walker to Leonard Horner, 17 May 1830. This archive is hereafter cited as 'UCC'.

ten candidates, in addition to De Morgan himself, do stand out from the rest. An examination of why these people were rejected could perhaps bring us closer to a reason for De Morgan's appointment.

Peter Nicholson (1765-1844), one of the earliest entrants, was already a well-known mathematician and architect. Appointed architect to the county of Cumberland in 1805 on the recommendation of Thomas Telford, he had from 1810 been giving private lessons in mathematics, land surveying, geography, navigation, mechanical drawing and fortification in London. His published works included the *Architectural Dictionary* (1827) and *Rudiments of Algebra* (1819) in which he invented a method for obtaining the rational roots, and approximating to the irrational roots, of an equation of any order.¹⁶ Although he had been involved in a minor controversy on the subject with Leonard Horner (who, in 1827 held the influential position of Warden of London University) in 1819-20, it is unlikely that personal antagonism was a reason for Nicholson's rejection. More likely factors were his age and the fact that his skills were more vocational than academic.

John Radford Young (1799-1885), was from 1833 to 1849 professor of mathematics at Belfast College. A protégé of Olinthus Gregory, his first book, *An Elementary Treatise on Algebra* was published in 1823. As a teacher, he is remembered for helping to familiarise students with continental methods of analysis. As a mathematician, his original discoveries include a proof of Newton's rule for determining the number of imaginary roots in an equation, published in 1844.¹⁷ This fine mathematician would undeniably have been nearly perfect for the job, with Gregory's influence no doubt adding extra credibility to his application - an application the council does not appear to have received.

Mathematician and later journalist John Herapath (1790-1868) was the most enthusiastic, persistent and argumentative of all the applicants. A mathematical tutor at the time of his application, he still harboured a grudge against the Royal Society for refusing to publish his paper 'A Mathematical Inquiry into the Causes, Laws, and Principal Phenomena of Heat, Gases, Gravitations, &c' seven years previously. He had become acquainted with Brougham, who invited him to write a treatise on the Differential and Integral Calculus for the Society for the Diffusion of Useful Knowledge (SDUK) and also, we assume, to try for one of the mathematical professorships.¹⁸ He wrote no less than ten quite lengthy

¹⁶ *D.N.B.*, **41**, 23-4.

¹⁷ *ibid*, **63**, 383-4.

¹⁸ *ibid*, **26**, 163-4.

letters to the council between April 1827 and April 1828, mainly inquiring whether they had yet reached a decision and enclosing further testimonials. By November, he had a "suspicion" that he "should not be elected to either of the Mathl professorships"¹⁹ and, in a letter to Brougham of that month, he reiterated his strong desire to be selected. "If amidst all the facts and circumstances....," he wrote, "I am now thrown out of both Chairs, unless in favour of more able men, which will soon be known, I am free to acknowledge, as I have to Dr Gregory, that however long I may live, I shall always regard it as the most hard, cruel, & unjust treatment I have ever experienced."²⁰ This constant badgering of council members, along with his conceited belief in his own intellectual superiority and the Royal Society controversy, ensured Herapath's eventual rejection. He gave up teaching in 1832.

The Rev. Dionysius Lardner (1792-1859) is most famous for his *Cabinet Cyclopaedia* series, published between 1829 and 1849. A scholar of Trinity College Dublin from 1813 to 1827, he was already a regular contributor to the *Edinburgh Review*, the *Encyclopedia Edinensis* and the *Encyclopedia Metropolitana*, having published four books - on algebraic geometry, calculus, plane and spherical trigonometry and the first six books of Euclid - plus a work entitled *Popular Lectures on the Steam Engine* for which he won a gold medal from the Dublin Royal Society.²¹ His friends in the scientific community were numerous and influential; Babbage and Whewell contributed testimonials.²² So wide-ranging were his talents that, in July 1827, rather than restrict him to mathematics, the council appointed him founder professor of natural philosophy,²³ which then encompassed experimental physics and what we would today call applied mathematics.

Interestingly, his successor in this chair, William Ritchie (1790-1837), was also an applicant for the mathematical post in 1827. More of a physicist than a mathematician, Ritchie was at that time rector of the Royal Academy of Tain in Scotland. He had published eighteen scientific papers, of which only two were mathematical (the rest dealing mainly with radiant heat, air-pumps and hydrostatics).²⁴ In 1826 he had spent a year in Paris, attending the lectures of, *inter alia*, Biot, Thenard, Gay-Lussac, Cauchy and

¹⁹ UCC, John Herapath to Henry Brougham, 19 Nov. 1827.

²⁰ *ibid.*

²¹ *D.N.B.*, **32**, 145-7.

²² Brit. Mus. Add MS 37183, f.463, Dionysius Lardner to Charles Babbage, 27 March [1827]; UCC, Dionysius Lardner to Henry Brougham, n.d.

²³ Education Committee Minutes, 22 June 1827; *The Times*, 14 July 1827, 2e.

²⁴ UCC, William Ritchie to Leonard Horner, 28 July 1827.

Ampère. He also acquired great skill in devising and performing natural philosophy experiments, becoming known to John Herschel and the Royal Society as "an experimenter of great ingenuity and merit".²⁵ Though not suited for the university's mathematical chair, he was appointed professor of natural philosophy at the Royal Institution in 1829.

Henry Moseley (1801-1872) was one of the only candidates to specifically apply for the higher mathematical chair. His first paper, 'On measuring the Depth of the Cavities seen on the Surface of the Moon', was published when he was only seventeen. A scholar of St. John's College Cambridge, he graduated as seventh wrangler in 1826.²⁶ Throughout the competition he was one of the clear front-runners, being short listed and invited for interview by the Education Committee in February 1828.²⁷ His rejection almost certainly rests on his inability to attend this interview due to the Committee's failure to give him adequate notice. A letter from his brother, dated 18 February, the appointed day, claims that the invitation had only just arrived, thereby rendering it impossible for him to get to London in time.²⁸ By the next day, Moseley's name had been deleted from the list.²⁹ Denied a career at London University, he later accepted a post from its new rival King's College, serving as their first professor of natural and experimental philosophy and astronomy from 1831 to 1844.

By another strange coincidence, the founder professor of mathematics at King's was also a candidate. Thomas Grainger Hall (1803-1881), a graduate and fellow of Magdalene College Cambridge, was fifth wrangler in 1824, and had been working for three years as a public and private tutor in Devon. Specialising in mathematical analysis and its applications, Hall was forced to withdraw suddenly from the competition only a matter of weeks after first applying. "The cause which has led to this sudden change," he wrote to Brougham in November, "is this: that if I leave Cambridge and come to you, I lose my Fellowship & every right and interest in the College....Being thus situated without the resources which many men have, should ill health make me unfit for the discharge of my public duties, on my fellowship have I only to depend."³⁰ Clearly, the senior fellows of Magdalene were determined to prevent their college from being in any way associated

²⁵ *D.N.B.*, **48**, 326.

²⁶ *ibid*, **39**, 175-6.

²⁷ Educ. Ctte. Minutes, 7 Feb. 1828.

²⁸ UCC, William Moseley to Leonard Horner, 18 Feb. 1828.

²⁹ Educ. Ctte. Minutes, 19 Feb 1828.

³⁰ UCC, Thomas Hall to Henry Brougham, 5 Nov. 1827.

with "the godless institution on Gower Street", leaving Hall with no alternative but to wish the new university success and "regret that illiberality & unfounded prejudices should have prevented me from being one of its first Members".³¹ It comes as no surprise that, nearly three years later, in July 1830, Magdalene did nothing to prevent Hall's appointment to the Anglican King's College.

Another Cambridge man with similar credentials was Charles John Myers (1801-1870). Like Hall, he had been the fifth wrangler of his year (1823, when Airy came first). He too had been working for four years as a private tutor. Similarly, he was a fellow - of Trinity College - but, unlike his unfortunate contemporary, his college made no attempt to obstruct his application. A friend of Airy, he had just published a short work on the differential calculus and was currently employed as a college examiner, setting papers on algebra, solid geometry and conic sections.³² His eight testimonials include enthusiastic contributions from Airy and Whewell. When the Education Committee chose their first shortlist in early February 1828, Myers, like Moseley, was on it.³³ However, by 19th of that month, both he and Moseley had been rejected.³⁴ Reasons for Myers' elimination are harder to ascertain. He seems to have presented himself before the committee for interview and his references were all very good. However, Airy's letter of recommendation, though almost certainly unintentionally, does seem to suggest that Myers' talents lay primarily in algebra and analysis rather than in all areas of the subject, ending with the words "a person better fitted for the Algebraical Professorship than Mr Myers can scarcely be found".³⁵ Moreover, excellent though Myers' testimonials were, he chose virtually the same referees as another candidate from Trinity whose endorsements were even more impressive than his own; that candidate was De Morgan himself.

Along with Myers and De Morgan, the Rev. Frederick Leicester (d. 1833) was one of the last few to apply. Another Trinity scholar, he had been Senior Wrangler in 1815 and, as seems traditional, had become a private tutor. Not rejected until the day of De Morgan's election, Leicester's chief flaw appears to have been that his references dwelt too heavily on his skills in the abstract branches of the science. On 14 February 1828, he wrote to Leonard Horner: "From intelligence which I have recently heard, I have been led to suppose that it might be desirable for me to obtain testimonials of a different character

³¹ *ibid*, 30 Jan. 1828.

³² *ibid*, Charles Myers to Leonard Horner, 4 Feb. 1828.

³³ Educ. Ctte. Minutes, 7 Feb. 1828.

³⁴ *ibid*, 19 Feb. 1828.

³⁵ UCC, George Biddell Airy to Council, 7 Jan. 1828.

from those which I have already sent in."³⁶ The same day, Gregory recorded "another visit from Mr. Leicester, who proposes to send me some papers in order to prove that he has been all along attentive to the practical applications of mathematical science".³⁷ One can only assume that these were not satisfactory.

Yet another Trinity graduate (nineteenth wrangler in 1821) was Thomas Hewitt Key (1799-1875). Key came very close to the concept of the complete Renaissance man. After taking his B.A. at Cambridge, he studied medicine from 1821 to 1824 before accepting the position of professor of mathematics at the newly-founded University of Virginia in 1825. He resigned two years later, due to the unsuitability of the climate, and applied to London University. Following his failure to procure the mathematical chair, he was appointed professor of Latin in July 1828,³⁸ a post he exchanged in 1842 for the professorship of comparative grammar, which he held for the rest of his life.³⁹ Along with the mysterious "Mr. Ward", of whom absolutely nothing is known, Key's letter of application no longer survives - only references to him in the council minutes provide any evidence for his having once been a candidate. Eventually rejected in favour of De Morgan, the following extract from a letter written by Gregory reveals why: "My objection to Mr Key's testimonials is, that they are not sufficiently specific. The American testimonials have evidently this defect ..., and if [one were to] turn to the documents from Cambridge, what information do they supply? Simply that Mr Key distinguished himself in *pure mathematics*. This again, in my estimation, is not sufficiently specific. What do the certifiers mean by *pure mathematics*?"⁴⁰ So, as was the case with Frederick Leicester, Key's testimonials appear to have done more harm than good.

These, then, were De Morgan's principal opponents. Given the right circumstances, any one of them could have been chosen instead of him. However, the thirty-one men so far mentioned were not the only individuals who had the chance to be selected. Unknown to any of the contestants, two people had already been offered the chair during the course of the competition. Furthermore, neither of them were candidates, although the council no doubt wished they had been. Arguably two of the most respected and talented British mathematicians of the early nineteenth century, they were none other than Charles Babbage and John Herschel.

³⁶ *ibid*, Frederick Leicester to L. Horner, 14 Feb. 1828.

³⁷ *ibid*, No. 765, Olinthus Gregory to Leonard Horner, 14 Feb. 1828.

³⁸ *ibid*, No. 840, Thomas Hewitt Key to Council, [July 1828].

³⁹ *D.N.B.*, **31**, 84-5.

⁴⁰ *UCC*, No. 404.

2.1.3 Babbage and Herschel's involvement

Although the council had advertised two mathematical chairs, elementary and higher, the overwhelming majority of early applications were for the former position. By the first deadline of 1 May 1827, ten applications had been received, eight of which were for the elementary chair. However, at this early stage, it was the higher chair which the council appear to have been most anxious to fill. Very naturally, they aimed for men of high standing, as is corroborated by the following letter, received by Charles Babbage on 20 February 1827, less than two months into the competition:

My Dear Sir,

May I be allowed to state to the Council of the London University, that you would accept the office of Professor of the Higher Mathematics and Mathematical Physics, if elected - I would in that case make use of the information at a fit opportunity, and save you the trouble of writing a letter declaring yourself a Candidate.

Yours,

Henry Warburton.⁴¹

Although no reply survives, it is very obvious that Babbage turned the offer down, being far more interested in standing for the vacant Lucasian Professorship at Cambridge, to which he was appointed in March 1828.⁴² It is not hard to determine his reasons: Cambridge offered prestige and security while the best he could hope for in London would have been a modest income and an insecure future. A year after the above letter was sent, geologist Charles Lyell was writing "that the University do not guarantee such a minimum as can warrant a man, who has anything certain to give up, in venturing....for Babbage viewed it in this light when offered the mathematical chair. 'What they will secure to me,' he said, 'is no more than I could make in the same number of hours by authorship, and get more fame. They have no dignity to confer as yet, they have their reputation to make. I have not. If, as they admit, they wish to get some from me, why they ought to buy it, and pay for it.' "⁴³

⁴¹ Brit. Mus. Add MS. 37183, f.454, Henry Warburton to Charles Babbage, 20 Feb. 1827.

⁴² Royal Society Herschel Papers (hereafter 'Royal. Soc.'), MS.HS 2.222, John Herschel to Charles Babbage, 9 March 1828.

⁴³ *Life, Letters and Journals of Sir Charles Lyell, Bart...* (Edited by Mrs. Lyell), Vol. I, (London: John Murray, 1881), 178.

Oblivious to this set-back, applications continued to arrive. In May, the Education Committee concluded that the best candidates thus far were Lardner for higher mathematics and experimental physics, Moseley and Herapath for higher mathematics, and Butts for the elementary professorship,⁴⁴ but they refrained from making an appointment in case more eligible applications arrived. None did. The decision to give Lardner the natural philosophy chair⁴⁵ only reduced their meagre options. The expected deluge of applications from well-known and prominent mathematicians had not materialised. It was at this point that the second offer was made, this time to John Herschel.

In a letter to him dated 30 June 1827, Henry Brougham stated: "The Council of the London University have desired me to submit to your consideration a proposal for taking the Professorship of the Higher Mathematics....But we are also quite convinced that for the first 2 or 3 years there can be little teaching (*if any*) required in that Class. The University opens in Oct. 1828 and before 1830 we expect little attention will be required in that high department....If you found the labour more than I describe it, we should not consider you bound to continue."⁴⁶

Although they had no way of knowing it, the council's offer could not have been made at a more inappropriate time in Herschel's career. By 1827, his astronomical research was occupying such a vast proportion of his work that he found himself obliged to cut back on the amount of time he devoted to other pursuits in order to accommodate it. He had already turned down the offer of becoming a candidate for the Lucasian chair⁴⁷ and just three days before he received Brougham's letter had resigned his position as Secretary of the Royal Society.⁴⁸ His reply to the council was polite but to the point. While deeply honoured by such a flattering offer and certain of the university's success, he feared that "continued residence and the performance of regular duties in London are altogether incompatible....with my other pursuits, I may almost call them duties, which have the strongest claim on my attention".⁴⁹

⁴⁴ Educ. Ctte. Minutes, 17 May 1827.

⁴⁵ *ibid*, 22 June 1827.

⁴⁶ Royal Soc. MS.HS 4.303, Henry Brougham to John Herschel, 30 June 1827.

⁴⁷ *ibid*, MS.HS 9.487, John Herschel to T. W. Hornbuckle, [Oct. 1826].

⁴⁸ *ibid*, MS.HS 26.62, John Herschel to Henry Kater, 27 June 1827.

⁴⁹ UCC, No. 407, John Herschel to Henry Brougham, 1 July 1827.

Brougham and the council were not to be put off that easily. So keen were they to install a mathematical professor of such reputation that Brougham wrote back, urging Herschel to reconsider. "No duties," he insisted, "will be required of you which can possibly interfere with any private pursuits for two or three years....We all think that the University will benefit much by your being seen during those years connected with it - tho' you should not lecture at all."⁵⁰ But Herschel's mind was made up. His next letter was of necessity more specific to avoid any possible doubt as to its meaning: "The circumstances and pursuits alluded to in my last are not of a temporary nature, and would equally prevent me at a future period as at present from being efficient as a professor so that in fact were I now to fill that office, it would be with not merely an option afforded me, but an understood certainty on my part that I must resign it so soon as its duties become...real."⁵¹ Finally, as if to reinforce his determination to adhere to his decision, he added: "To teaching I have a positive dislike, and would certainly engage in no office in which it formed any part of the duties expected of me."⁵² As far as he was concerned, the matter was closed.

Saddened by this second rejection, the council had no further discussion on the subject until the end of the year, concentrating instead on the other professorships. No reference was made to mathematics in the public announcements of appointments that July, so letters of application continued to arrive. However by late December, the education committee had come to the conclusion "that persons had perhaps abstained from applying for it from a supposition that it had already been filled up".⁵³ Two days later, on 22 December 1827, the council agreed to re-advertise the vacancy and extended the deadline to 1 February 1828.⁵⁴ More significantly, on 12 January, again on the recommendation of the committee, the council abandoned the idea of two professorships, resolving "that for the present, the Elementary & Higher Mathematics be taught by one Professor".⁵⁵

This decision immediately eliminated all those who had applied solely for the elementary professorship. Discounting Lardner (who now had an appointment), Hall (who had withdrawn), and those whose applications were never registered, this left only Key, Moseley, Myers, Leicester, Herapath, Angus, Ward, Wallace, and one final applicant, for

⁵⁰ Royal Soc. MS.HS 4.305, Henry Brougham to John Herschel, [July 1827].

⁵¹ *ibid.*, MS.HS 4.306, John Herschel to Henry Brougham, [July 1827].

⁵² *ibid.*

⁵³ Educ. Ctte. Minutes, 20 Dec. 1827.

⁵⁴ Council Minutes, vol. I, f.131.

⁵⁵ *ibid.*, f.137.

the committee to consider. This contestant was a "Scholar of Trinity College, Cambridge,...desirous of becoming a Candidate for the Mathematical Chair in the University of London",⁵⁶ whose letter of application had been received by the council on the very day they agreed to re-advertise the position. At only twenty-one years of age, he was the youngest contender, with no teaching experience, publication record or professional qualification. He was, of course, Augustus De Morgan.

On 7 February, he was shortlisted by the education committee with four others: Key, Moseley, Myers and Leicester. This list was reduced to three, with the rejection of Moseley and Myers, on the 19th. Finally, at their seventy-first session, on Saturday 23 February 1828, the council, "having deliberated upon the qualifications of these candidates resolved that Mr. Augustus De Morgan be appointed professor of Mathematics".⁵⁷ The first English university to be founded since the middle ages had thus seen fit to appoint a relative novice as one of their founder professors in preference to men more experienced and better qualified. In order to at least partially explain this decision, what now remains is to examine De Morgan's credentials, as presented to the council in 1828, to come to some estimate of how he was able to distinguish himself from his competitors.

2.1.4 De Morgan's Application and Testimonials

For De Morgan, the establishment of London University was welcome not only on ideological grounds but also because it gave him an opportunity to abandon the study of law, in which he was far from happy, in favour of his favourite pursuit, mathematics. We do not know how or when his attention was first drawn to the vacancy, although it is likely that he saw an advert in the papers like most of the other candidates; perhaps he only found out about the job at a late stage in the process. Maybe, being understandably intimidated by so vast a responsibility at such a young age, he took several months consulting old friends and colleagues to determine if they believed he was capable of such an undertaking. He was certainly advised against it - "for his own family and near relations, who had anticipated a brilliant success for him at the Bar, felt that to take a position as yet doubtful, with a greater doubt of fitting remuneration was really a sacrifice on his part"⁵⁸ - but, whatever the advice may have been, by the end of the year he had submitted his formal application.

⁵⁶ UCC, De Morgan to Leonard Horner, 22 Dec. 1827.

⁵⁷ Council Minutes, vol. I, f.152.

⁵⁸ S. E. De Morgan, *op. cit.*, (13), 28.

In his letter of candidature, De Morgan had referred "the Council to the Tutors of Trinity College, and to his degree in the Tripos of 1827, for testimonials of qualifications &c".⁵⁹ Yet although the council received testimonials in favour of De Morgan's candidature from all seven of his former tutors, only those from Coddington, Hamilton, Higman and Whewell survive. Nevertheless, if these are typical of the rest, the council cannot fail to have been impressed by such solid endorsements of academic suitability. The following extracts will give a flavour of their contents:

Higman : "His mathematical attainments on his first entering the university, at the early age of 17, were very considerable, and these became so matured by indefatigable industry & a peculiar genius for the abstract sciences, that at the time of taking his degree of BA, his knowledge of the Pure & Mixed Mathematics placed him among Geometers of the very first order."⁶⁰

Coddington : "The distinction which he obtained (that of fourth Wrangler) is hardly a just criterion of his merit, as his reading had been so extensive that it could not all be made available in an examination here, though likely to prove of great service in another place."⁶¹

Whewell : "He was considered and I believe most justly, while at Cambridge, as very eminently gifted with mathematical talent, and possessed of unusual skill in various departments of analysis; and was always reckoned in these respects equal to the very first of his contemporaries....I believe Mr De Morgan to be strongly attached to mathematical pursuits and likely to follow them far & successfully."⁶²

Hamilton : "His Scientific Attainments are extensive and profound. He is accurately versed in the writings of the Foreign Analysts; and I may be permitted to express my firm Belief, that, had he directed his Attention more exclusively to the Works of the English Mathematicians, he would have obtained the first Academical Honor of his Year."⁶³

⁵⁹ UCC, De Morgan to Leonard Horner, 22 Dec. 1827.

⁶⁰ *ibid*, John Philips Higman to Council, 12 Jan. 1828.

⁶¹ *ibid*, Henry Coddington to Council, 14 Jan. 1828.

⁶² *ibid*, William Whewell to Leonard Horner, 31 Jan. 1828.

⁶³ *ibid*, H. Parr Hamilton to Council, 30 Jan. 1828.

Higman : "...and both his ardour for science and a conscientious regard to the duties of his office would lead him to promote in every manner possible the important objects for which the University of London has been formed."⁶⁴

Even though virtually no testimonials for any other candidates exist, we have seen that those of others, especially his principal opponents Key and Leicester, were criticised by the council for their lack of specific information. The above extracts show that this charge most certainly could not have been laid against those supporting De Morgan. Although emphasising his skill in the more abstract side of the subject, especially analysis, they also take pains to stress his all-round mathematical talent and knowledge. The only other applicant for whom testimonials survive in any quantity is Charles Myers, and, of these references, Whewell's is the only one of any significant length and content, the rest being bland, brief and predictable, particularly that of Higman. Interestingly, he had written one of the most lavish of De Morgan's testimonials as well as a personal letter to George Birkbeck, sent on the final day of the contest, in which he made one final appeal on De Morgan's behalf.

Trin Coll Camb. Feb^y 1 1828

My Dear Sir

A few weeks since I sent a testimonial in favor of a highly esteemed pupil & friend of mine Mr De Morgan who is candidate for the Mathematical Professorship in the London University, and I now beg to solicit your interest in his favor, from the perfect conviction which I feel that out of all the names who have hitherto appeared he is out & out the fittest person for that most important Professorship. Though young in years De Morgan possesses a strong, powerful understanding with abilities that would enable him to shine in any profession that he would choose to adopt; & indeed nothing surprised me more than his intention to come forward as a candidate for the Mathematical Chair, as I always understood that his fixed determination was to pursue his legal studies, & to give up his chance for a fellowship in order to pursue them. De Morgan was 4th Wrangler in a year distinguished beyond most others for mathematical talent : and from the

⁶⁴ *ibid*, J. P. Higman to Council, 12 Jan. 1828.

very intimate & personal knowledge which I have of his talents, attainments & most excellent good temper & his position, I should venture to say that any college or university would secure a prize in obtaining him. I can only say as far as regards my own opinion that I know no one whom I should prefer as my own mathematical lecturer, if there were a vacancy, or that were possible. I hope you will appreciate from my warmth of friendship for De Morgan & the great esteem in which I hold him my application to you on this occasion as I am not quite certain a letter of private application of this kind is strictly correct. Feeling however as I do a very strong wish that the London University would do well, & knowing at the same time how much its success must depend on the Professors which it will first appoint, I cannot but feel a most earnest desire that the Mathematical Chair may be first filled by De Morgan.

I remain dear Sir
Yrs Very Sincerely
JP Higman.⁶⁵

For a referee to send in two testimonials was rare, but to demonstrate such admiration and esteem for one so young and to exhibit such a profound and unwavering belief in the necessity of selecting this particular candidate over all others was unusual, to say the least. It is hard to imagine that the council received higher endorsement for any other candidate; even the rest of De Morgan's own testimonials pale in comparison to Higman's fulsome praise. Thus, while it would be very wrong to attribute De Morgan's selection to the influence of this letter alone, there can be no doubt that it played a major part in the eventual decision of the council.

So perhaps did a manuscript which has been lying in the University College archives, unpublished and virtually unread for well over a century. An inscription in its author's hand, made twenty-five years after his election, can still be found inside: "This is the first attempt I ever made at writing for publication. It was commenced at the proposal of the Useful Knowledge Society in its earliest days - but was never published, nor even completed. I sent it in with my testimonials when I was a Candidate for the Mathematical chair in the University of London in 1827, and I think it was as useful as the testimonials."⁶⁶ De Morgan had become involved with the SDUK in March 1827, almost

⁶⁵ *ibid*, J. P. Higman to George Birkbeck, 1 Feb. 1828.

⁶⁶ Augustus De Morgan, "Elements of Statics", University College London Archives, MS. ADD. 27.

immediately after moving to London, most probably to keep in touch with the sciences while he laboured under his legal studies. In August, he agreed to write a treatise on statics for publication by the society,⁶⁷ working on it that summer (i.e. before his application to the university). The result was a sixty-six folio manuscript entitled "Elements of Statics".

The book is arranged into six chapters. The first preliminary chapter begins with a three page epistemological and historical introduction to the subject of mechanics before defining such terms as impenetrability, inertia, force, weight and mass, concluding with a demonstration that $W=Mg$, where g is the intensity of a force. Chapter two deals with the equilibrium of a point, using various examples and problems to discover what relations must exist between various forces to keep a particle in equilibrium. It also contains a definition of virtual motion. Chapter three, 'On the Center of Gravity', uses differential and integral calculus to find centres of gravity for many different surfaces and bodies. The fourth chapter generalises results used in chapter two, using Lagrange's demonstration that the Principle of Virtual Velocities holds just as well for a system as for a point and goes on to determine conditions for stable and unstable equilibria in certain systems. Chapter five develops this still further by finding these conditions for any rigid system whatsoever, and the final chapter considers motion in a system with a fixed axis, i.e. rotation.

Perhaps the most surprising thing about this tract to anyone familiar with De Morgan's work is that it is concerned with *applied* mathematics, an area on which he later published nothing, being far more interested, it would seem, in pure mathematics and logic. However, a characteristic feature is its intensive use of functional equations and calculus, both of which he was to devote much attention to in his subsequent career. It also demonstrates a thorough knowledge and understanding of recent work on the subject, especially that of Laplace, Lagrange, Lacroix and other European writers - evidence of the extensive reading referred to by his tutors. Interestingly, no mention is made of couples, the major mechanical innovation of the time and a striking omission from an elementary work.

Yet "Elements of Statics" is far from elementary; indeed, by the later chapters it is very high-powered. (The author's intention, had he finished the work, was to write an

⁶⁷ SDUK Archives, University College London, De Morgan to Thomas Coates, 6 August 1827.

accompanying book on dynamics, providing the student with a complete course in mechanics from first principles to the *Méchanique Céleste*.) In fact, it is unlikely that the SDUK would have published it as an introductory work, its title being something of a misnomer. Nevertheless, "Elements of Statics" demonstrated to the council that, while De Morgan had yet to publish anything, he was clearly capable of producing mathematical work of a very high standard. Moreover, by its clear, well-ordered presentation, it showed his ability to arrange a course into a progressive series of subjects, each proceeding in manageable stages capable of being intelligible to the student. In other words, it showed his ability to teach.

2.1.5 Inspiration or Desperation?

We have thus seen how factors such as the other candidates, rejection of the post by Babbage and Herschel, extension of the deadline, amalgamation of the two chairs and excellent testimonials all helped to secure the professorship for Augustus De Morgan. However, in such a complex case, there are still more explanations which can be given. Reminiscing over three decades later, De Morgan attributed his success to the influence of Brougham and Warburton, despite the alleged opposition of Gregory.⁶⁸ No evidence exists to corroborate or refute this opinion. Malicious rumours at the time claimed that he owed his election to the good offices of William Frend (1757-1841), a London mathematician, actuary and one of the four original auditors of the university, whose daughter De Morgan was later to marry. This is almost certainly false. Frend would have had no such influence, never having been on the council or the education committee. In any case, at the time of the election, he was convalescing in Cheltenham having resigned his post some time before due to poor health.

A more probable explanation was that the new university faced an uncertain future, both academically and financially. This undoubtedly played a major part in many deciding not to participate, as witness a letter from the mathematician George Harvey to Babbage written during the competition: "With respect to the London University, a sort of fatality has been about it. When I was in Town, no one seemed to know any thing about it; and in a letter which I received from Dr Gregory on the subject, the income did not seem to be of that kind that would induce me to try for it."⁶⁹ Realising the precarious nature of their undertaking, the council would therefore be more inclined to employ someone who had

⁶⁸ S. E. De Morgan, *op. cit.*, (13), 312; Royal Soc. MS.HS 6.358, De Morgan to John Herschel, 9 Aug. 1862.

⁶⁹ Brit. Mus. Add MS. 37184, f.43, George Harvey to Charles Babbage, 24 May 1827.

nothing to lose financially and who was willing to take a risk than a more seasoned academic who would abandon them at the first sign of monetary difficulty.

Any incredulity we may feel on hearing of De Morgan's appointment at such a young age is largely fuelled by a natural assumption that it was a highly prized position. However, though such a post would undoubtedly be considered so today, it should be borne in mind that in 1828, the new university had many other constraints to contend with, of which financial uncertainty was only one. Firstly, it was not, strictly speaking, a university at all. Despite the parliamentary efforts of Brougham and others, all attempts to obtain a royal charter were consistently defeated. Thus the self-styled university had no authority to award degrees, offering instead Certificates of Honours for each course and a General Certificate after completion of three years approved study.⁷⁰ This resulted in contemporaneous claims that "[a]ny set of men might as well affect to constitute themselves a corporation in an unchartered town, as these persons to set up a University!"⁷¹

Secondly, we have to remember that, since the geography of the capital has changed so dramatically in the last century and a half, the university was situated on what then was the northern edge of London. Its site "was the last fragment not yet built upon of the Long Fields which lay north of Bedford and Montague Houses and between what are now Gray's Inn Road and Tottenham Court Road... The builders had not yet made Camden Town one with London, and there was open country beyond."⁷² This location had previously been used "as a drilling ground, a place for duelling and as a rubbish dump".⁷³ Hardly an auspicious central location for a 'London' University, it contrasted sharply with the prime site provided for the conformist King's College on the Strand a year or two later.

Finally, the whole enterprise had to endure much bitter opposition and criticism from many areas throughout its early years. This antagonism was provoked "partly by the apparent pretension of a joint-stock company masquerading as a university in a period of financial speculation; partly by the College's appeal to social groups excluded from the two old universities, an appeal intolerable to the Establishment; most of all, it was

⁷⁰ Negley Harte & John North, *The World of UCL 1828-1990*, (London: University College London, 1991), 46.

⁷¹ *The Quarterly Review*, **39**, (1829), 128.

⁷² Bellot, *op. cit.*, (4), 35.

⁷³ N. Harte & J. North, *op. cit.*, (70), 21.

provoked by the rejection of all religious teaching and of compulsory religious conformity".⁷⁴ It was even claimed "that to educate youth in the metropolis was to court their physical decline and their moral ruin".⁷⁵ As a consequence of these obstacles, and being able to offer only small emoluments, the council had to content itself with men of less reputation than it had initially aimed for.

However, not all the first professors were unknown. Perhaps the most prestigious appointment was that of Charles Bell (1774-1842) to the chair of surgery.⁷⁶ A graduate of Edinburgh University and a good friend of Campbell and Brougham, we are told "his influence upon the appointments to the medical chairs seems to have been great".⁷⁷ Anthony Todd Thomson (1778-1849), a well known London practitioner, was made professor of materia medica. A contemporary of Bell at Edinburgh, he was also friendly with Brougham.⁷⁸ John Ramsay McCulloch (1789-1864) was an outstanding appointment to the professorship of political economy, being a recognised authority on the subject. Another Edinburgh man, he was a prominent contributor to the *Scotsman* and the *Edinburgh Review*.⁷⁹

But if some received their appointments through fame and contacts, it would seem that other less advantaged professors were appointed through simple good fortune. We have already noted how luck played a part in De Morgan's appointment. Similar providence attended the election of the relatively unknown Edward Turner (1798-1837) to the chair of chemistry. Yet another Edinburgh graduate, Turner was appointed in the light of an embarrassing lack of suitable candidates and the rejection of the position by Thomas Thomson (1773-1852) and Michael Faraday (1791-1867).⁸⁰ John Lindley (1799-1865), the first professor of botany, was not even a graduate, although he had had the distinction of being librarian to the President of the Royal Society, Sir Joseph Banks.⁸¹ Despite their comparative anonymity, both men, via their lectures and publications, would soon attain a wide reputation in their respective subjects.

⁷⁴ *ibid*, 31.

⁷⁵ Bellot, *op. cit.*, (4), 62-3.

⁷⁶ *D.N.B.*, 4, 154-7.

⁷⁷ Bellot, *op. cit.*, (4), 40.

⁷⁸ *D.N.B.*, 56, 235-6.

⁷⁹ *D.N.B.*, 35, 19-21.

⁸⁰ Bellot, *op. cit.*, (4), 41.

⁸¹ N. Harte & J. North, *op. cit.*, (70), 37.

Yet research, while important for enhancing their academic standing, was no official part of the new professors' duties. Indeed, Campbell had even suggested in 1825 that authorship be viewed as an impediment to the adequate fulfilment of teaching obligations.⁸² Although this recommendation was not implemented, to supplement their incomes, professors such as Lardner and McCulloch "joined London's lecturing empire, drawing on while feeding the appetite for self-improvement in their audiences".⁸³ However, they were soon to find the printed page far more lucrative than the lecture theatre. The new university was thus, first and foremost, a teaching institution; therefore the noticeable absence of published works prior to his appointment can be seen as anything but a handicap for the young De Morgan.

Two characteristics unique to De Morgan may also have influenced the council's decision. Firstly, his youth. In the first few years of its existence, the council were to prove themselves almost dictatorially authoritarian and probably thought that a naïve young professor would work to their advantage, being easy to influence and control. They were to be proved very wrong. Secondly, although clergymen had been made professors in the university (Dionysius Lardner, for example), it remained completely secular in outlook and character, regarding the appointment of scholars from all religious backgrounds as a clear illustration of this. De Morgan's nonconformist tendencies would thus have been an extra point in his favour when the council came to make their final decision.

His Cambridge education was also unquestionably a major factor in his success, since Cambridge was, at this time, the only place in England to produce first-rate mathematicians. As far back as 1825, *The Times* was saying that "it is known to be the intention to choose classical professors at Oxford, and mathematical at Cambridge",⁸⁴ hence the council's desire to enlist Babbage and Herschel, and the fact that all five candidates in the first shortlist were Cambridge men. Yet it was not just *where* he was educated but the *breadth* of his education which won him the chair. The council were looking for "a man of enlarged knowledge, and liberal mind, no mathematical sectarian; but one who knows *well* what was done by the ancients, what in the middle ages, and what has been done during the last thirty years, not merely in France, but in other parts of Europe".⁸⁵ Moreover, "the appointments would be given to those who were found most

⁸² *The New Monthly Magazine*, **13**, (1825), 404-19, p.415.

⁸³ Jack Morrell & Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science*, (Oxford: Clarendon Press, 1981), 19.

⁸⁴ *The Times*, 21 July 1825, 2e.

⁸⁵ UCC, No. 404, Olinthus Gregory to Leonard Horner, 19 Dec. 1827.

worthy; and if the merits, however little known, should be found to surpass those of others the most celebrated,..., the former would certainly be preferred".⁸⁶

Thus, while we can never give a truly comprehensive account of the underlying motives behind De Morgan's selection, many explanations can be given. He was certainly very fortunate, but luck does not account for the outstanding mathematical skill and knowledge which he had accumulated by such a young age. Similarly, while these highly developed abilities explain the magnificent set of testimonials in his favour, they cannot take the full credit for securing him the post. His appointment was, in the end, due to a combination of a series of fortuitous events and the recognition of academic potential. But if one had to encapsulate the fundamental reason for De Morgan's appointment it would be that, of those from whom the council were at liberty to choose, he fitted the bill the most satisfactorily.

2.2 Initiation

2.2.1 Congratulation

On 24 February 1828, the successful candidate received a brief note "informing you that the Council yesterday elected you professor of Mathematics after the most distinguished competition that there has been for any chair".⁸⁷ This letter was intended to be the first communication of the result prior to official notification. But De Morgan was already well aware of his election, having been present at the University on the previous day, when the decision was made:

It was a little characteristic incident connected with the appointment of the future Mathematical Professor, that while the election was going on in one part of the college, and he with some others of the candidates were in the common room, he took up a volume lying on the table, which proved to be Miss Porter's 'Field of the Forty Footsteps.' ... The love of fiction was strong enough in the candidate's mind to make him forget his interest in what was going on, and he had run through the volume before a whisper reached his ears as to the result of the election.⁸⁸

⁸⁶ *The Times*, 1 May 1827, 7a.

⁸⁷ University of London Library (hereafter 'ULL'), MS 322/5, Thomas Coates to De Morgan, 24 Feb. 1828.

⁸⁸ S. E. De Morgan, *op. cit.*, (13), 24-25.

News of his appointment soon reached his friends and former colleagues at Cambridge, who were not slow in writing to congratulate the new professor. "Few Things have afforded me, I assure you, higher Gratification than this welcome Intelligence," wrote Henry Parr Hamilton, continuing: "I confidently anticipate that you will not only assist materially in establishing the Reputation of the new University, but that you will enlarge the Boundaries of your favourite Science by the Opportunity you now have of devoting to it your exclusive Attention."⁸⁹ Not all his friends were so emphatic, however. William Frend's letter of congratulation expressed surprise at the abandonment of a promising career in the law for something far less lucrative. De Morgan responded:

You seem to fancy that I was going to the Bar from choice. The fact is that of all the professions which are called learned, the Bar was the most open to a person without interest, but my choice will be to keep to the Sciences as long as they will feed me. I am very glad that I can sleep without the chance of dreaming that I see an "Indenture of five parts" or some such matter held up between me and the *Mécanique Céleste*, knowing all the time that the dream must come true.⁹⁰

De Morgan had good reason to be pleased with his new position. For a man to have rejected all chance of a Cambridge fellowship due to religious convictions, the probability of finding an academic post in mathematics was slim indeed, a likelihood not helped by his youth and lack of reputation. The establishment of a mathematical professorship at a new secular university provided him with a unique opportunity to make a career out of mathematics. Yet his mathematical work was more than a vocation - it was a labour of love. Had he been unlucky in the competition and remained a lawyer for the rest of his life, it is inconceivable that he would have abandoned its study; his involvement with the SDUK would have ensured a long and steady supply of original publications, regardless of his lack of scientific employment. Yet, thanks to the risk taken by the council in February 1828, he was now in a position to focus completely on planning his mathematical output, starting with the course he would teach at the new university.

2.2.2 Preparation

The competition for the chair of mathematics had been so long in duration that De Morgan was one of the last professors to be elected. By the time of the final selections, in the summer of 1828, the council had made twenty-eight appointments, of whom twenty-

⁸⁹ ULL, MS 322/6, H. P. Hamilton to De Morgan, 27 Feb. 1828.

⁹⁰ ULL, MS 332/7b, De Morgan to William Frend, 15 March 1828.

six were professors. In line with the university's principle of religious impartiality, this initial professorship contained "three Clergymen of the Church of England, one Independent minister, a Jewish gentleman, who in his place of Hebrew professor taught the reading of the Old Testament, and other gentlemen nominally churchmen, but whose religious views were known to vary from strict orthodoxy to the widest latitudinarianism".⁹¹ The full list of academic staff of the new London University was as follows:-

Roman Language, Literature and Antiquities	Thomas Hewitt Key
Greek Language, Literature and Antiquities	George Long
Mathematics	Augustus De Morgan
Natural Philosophy and Astronomy	Rev. Dionysius Lardner
Chemistry	Edward Turner
English Language and Literature	Rev. Thomas Dale
French Language and Literature	P. F. Merlet
German Language and Literature	Ludwig von Mühlenfels
Italian Language and Literature	Antonio Panizzi
Spanish Language and Literature	Antonio Alcalá Galiano
Oriental Languages	Friedrich August Rosen
Hindustani	John Borthwick Gilchrist
Hebrew	Hyman Hurwitz
Political Economy	John Ramsay McCulloch
Jurisprudence and the Law of Nations	John Austin
English Law	Andrew Amos
Botany and Vegetable Physiology	John Lindley
Zoology	Robert E. Grant
Physiology and Clinical Surgery	Charles Bell
Anatomy	Granville Sharp Pattison
Materia Medica	Anthony Todd Thomson
Nature and Treatment of Diseases	John Conolly
Midwifery	David D. Davis
Clinical Medicine	Thomas Watson
Pathological Anatomy	Robert Carswell
Medical Jurisprudence	J. Gordon Smith

⁹¹ S. E. De Morgan, *op. cit.*, (13), 27-28.

Anatomy (Demonstrator)
Librarian

James R. Bennett
Rev. Francis Augustus Cox

As with the applicants for the mathematical chair, the most uniform characteristic of the university's teaching body was its relative youth, with only three being over forty and six aged thirty or less. At twenty-one, De Morgan was certainly the youngest, but not by far. The founding Professor of Oriental Languages, Friedrich Rosen (1805-1837), only twenty-two at the time of his appointment, was another exceptionally gifted young scholar.⁹² Trained in Göttingen and Leipzig, he had already earned "a very high reputation as an Oriental scholar, especially since the publication of his work on the roots of the Sanskrit".⁹³

Another noticeable feature of the professoriate was the strikingly innovative nature of many of their chairs. Many of the subjects listed above had never been taught at an English university, or even a European one. In particular, the chairs in English and the modern foreign languages were the first of their kind in Britain. The holder of one of these, the Italian professor Antonio Panizzi (1797-1879), shared a common interest with De Morgan: a love of books. Indeed it is for his work in this area that he is best remembered today. In 1831, to supplement his income, he became Assistant Librarian at the British Museum, being made Principal Librarian twenty-five years later, in which capacity he was largely responsible for the creation of the library catalogue and the Museum's famous Reading Room.⁹⁴

Two other professors who have not yet been mentioned, but are relevant to future events, are the professors of Greek and anatomy. George Long (1800-1879) had a very similar background to his colleague in the chair of Latin, Thomas Hewitt Key. A Trinity man (30th wrangler in 1822)⁹⁵ his first academic appointment had also been at the University of Virginia where he was the founder professor of ancient languages, a post he resigned in order to take up the chair of Greek at London University.⁹⁶ Like De Morgan, he was a prominent member of the SDUK, later editing their short-lived *Quarterly Journal of Education* (1831-5) and the twenty-nine volume *Penny Cyclopædia* (1833-46), to both

⁹² *D.N.B.*, 49, 247.

⁹³ *The Times*, 31 May 1828, 3c.

⁹⁴ *D.N.B.*, 43, 179-83.

⁹⁵ John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 4, 204.

⁹⁶ *D.N.B.*, 34, 102-4.

of which De Morgan was to contribute many articles. The two men became good friends, apparently having many common characteristics, such as "integrity of purpose and simplicity of character, indefatigable industry, and a love of fun which brightened hard work and kept us always amused".⁹⁷

Granville Sharp Pattison (1791-1851) had also spent some time as a teacher in America. Born and educated in Glasgow, in 1820 he had accepted the professorship of anatomy, physiology and surgery at the University of Maryland in Baltimore. He taught there for five years before resigning the post due to ill-health. Returning to Britain, in July 1827 he became one of the first professors to be selected for the new university, being appointed its professor of anatomy. An old-fashioned and rather quarrelsome character, Pattison was to play a central role in the controversy which was to engulf the new institution within a few years of its opening.⁹⁸

Ironically, the first appointment the council had made, at a special meeting on 30 May 1827, was not an academic one at all. This was the installation of Leonard Horner (1785-1864) as Warden, an appointment undoubtedly due, in part at least, to the influence of Henry Brougham, with whom he had been friendly since schooldays. Horner's career since graduating from Edinburgh University had seen his foundation of the Edinburgh School of Arts (now Heriot-Watt University) in 1821, as well as his term as a vigorous secretary of the Geological Society.⁹⁹ His role as Warden was basically to superintend the university's routine administration, such as external publicity, the purchase of books and laboratory equipment, and, ultimately, the admission and registration of students. Moreover, as secretary to the council, he was to act as the medium of communication between the governing body and their academic staff.

One of his first tasks had been to frame a statement of the council's intentions concerning the university's curriculum and constitution. A general outline had been published in the form of a *Prospectus* in May 1826, but after a year, more specific proposals were ready for public scrutiny. These were published in the form of a *Statement by the Council of the University of London* in July 1827, shortly after the first announcement of professorial appointments. This statement, incomplete though it inevitably was, had sufficed to keep

⁹⁷ S. E. De Morgan, *op. cit.*, (13), 103.

⁹⁸ F. L. M. Pattison, *Granville Sharp Pattison. Anatomist and Antagonist 1791-1851*, (Edinburgh: Canongate, 1987), 135-182.

⁹⁹ *D.N.B.*, **27**, 371-2.

the public informed of new developments as well as acting as an advertisement for the remaining professorships. However, by mid-1828, with most of the professors installed, a more substantial document was required to give the public more precise details of arrangements, especially regarding fees, eligibility and course structure. This was published as the council's *Second Statement* in June 1828.

The council defined two types of student who would be admitted to lectures: full-time, or regular, students, who were designated *Members of the University*; and *Occasional Students*, or "those persons, who, being already engaged in a profession, may still have leisure to improve their education by allotting a portion of each day to attendance on certain lectures".¹⁰⁰ This categorisation was somewhat vague, as pointed out by some of the professors, who doubted "the expediency, at least for the present, of any distinction of this kind. At all events if the terms be used at all, they should be clearly defined."¹⁰¹ *The Times* also noted the council's lack of clarity on this point, and attempted to elucidate by noting that the regular students "must submit to examinations and perform exercises as in other universities", whilst the latter category "are no more subject to the jurisdiction of the Council or the professors, than the persons who attend lectures in Albemarle-street".¹⁰²

No minimum age was specified for students, although the council assumed that those entering the University would have a modicum of elementary knowledge. But, as Brougham pointed out, "this was no more than an assumption, not a decree". He continued: "It should be remembered that the establishment...was a University, not a school.... Could it be imagined that the proprietors would send children of 10 years to be educated with those of 20? But ... the Council ... left the parents at liberty to send their children when they pleased; and if they were so foolish as to have them attend lectures unfitted for their years or faculties, they, and not the Council, were to blame."¹⁰³

In addition to the lack of age restriction, there would also be no entrance examination, although it was decided to divide those studying Latin, Greek and mathematics into junior and senior classes, of which the former would be designed for those "possessed of that

¹⁰⁰ *Statement by the Council of the University of London, Explanatory of the Nature and Objects of the Institution*, (London: Richard Taylor, 1827), 13.

¹⁰¹ UCC No. 972, Professors' Memorial, signed by Amos, Austin, Hurwitz, Davis, Dale, Pattison, Lardner, Thomson, Galiano, De Morgan and Bennett, 13 May 1828.

¹⁰² *The Times*, 26 June 1828, 7a.

¹⁰³ *ibid*, 28 Feb. 1828, 5e.

elementary knowledge which boys who leave school at fourteen or fifteen years of age have generally acquired".¹⁰⁴ Among the requirements for entry at this junior level were "that they shall be acquainted with Arithmetic to the extent of a knowledge of vulgar and decimal fractions, and be able to read an easy French prose author".¹⁰⁵ Entrance into the senior class was conditional upon satisfying the appropriate professor of one's proficiency in the earlier material. But before they could enter either class, prospective students were required to attend an interview "in order that the Professor may ascertain the state of preparation of the student...so that he may adapt his instruction accordingly".¹⁰⁶

Upon entry, however, students were free to determine which lectures they attended, there being no set course or "any order of study which it shall be imperative on the students to adopt".¹⁰⁷ Nevertheless, to earn the university's General Certificate, it was required to follow a recommended course of study in order to obtain the necessary Certificates of Honour, since "every student will be required to produce a certain number of Professors' Certificates, before he can be allowed to enter upon the examination for the General Certificate".¹⁰⁸ Thus, while those who wished to attend lectures without competing for honours were perfectly at liberty to do so, the council were adamant that "no student...who wishes to obtain a Certificate can be exempted from the examinations".¹⁰⁹

The final certificate was actually awarded after three years, although the prescribed programme extended for four. A good summary of this course is given by Bellot, in his history of University College:

In the first and second years the student was to take Latin (10 hours a week in the first year, 8 in the second), Greek (10), and Mathematics (6 and 4½). In the second year Natural Philosophy might be substituted for mathematics. In both there might also be taken French, German, or English composition (4½ hours). The third year was given to Logic and the Philosophy of the Human Mind (10 hours a week), Chemistry (6), and Natural Philosophy (5), and there was an increase in the number of optional courses both in languages and science. In the fourth year came Jurisprudence (3 hours a week), Political Economy (4), Natural

¹⁰⁴ *Second Statement by the Council of the University of London, Explanatory of the Plan of Instruction*, (London: Richard Taylor, 1828), 5.

¹⁰⁵ *Statement*, 14.

¹⁰⁶ *Second Statement*, 19.

¹⁰⁷ *Statement*, 13.

¹⁰⁸ *Second Statement*, 27.

¹⁰⁹ *ibid.*

Philosophy (3), and Moral and Political Philosophy (9½), and History was added to the list of optional courses.¹¹⁰

The system of instruction by lectures, exercises and written examinations was a deliberate departure from the traditional practices of the established English universities, being modelled on methods employed in the more progressive Scottish and German universities. Indeed, as *The Times* noted in its review of the scheme contained in the *Second Statement*, "It is, in fact, precisely the plan of the University of Edinburgh",¹¹¹ while the *Edinburgh Review* conformed to national stereotypes by praising the value for money offered by the range of lectures available.¹¹²

Fees were payable for each course of lectures (i.e. subject) taken per year, with proprietors and donors being entitled to present students for admission at a set rate. However, for those who were not nominated by shareholders, an extra payment of one pound and ten shillings was required per lecture course taken, up to a maximum of £4 10s. In addition to this, regular students had to pay a matriculation fee of £2, entitling them to use the library and other university facilities for four successive sessions. Occasional students paid a reduced rate.¹¹³ After all these expenses were covered, the average annual cost for a nominated student came to £22 7s 6d - far cheaper than the expense of residence at Oxford or Cambridge, but still well above the means of the working man.¹¹⁴

These fees were paid to the Warden at the commencement of each session, all money going into the university account. From this, the professors were entitled to draw their appropriate share during the year. The fee comprised "the remuneration to the Professor, and a payment to the fund from which the annual expenses of the University are to be defrayed".¹¹⁵ The proportions were calculated in the following way. If a particular professor's fees amounted to £300 or more, the total was divided between him and the university, the professor receiving two-thirds. If the total lay between £100 and £300, the professor would keep the first hundred pounds and the remainder would then be equally

¹¹⁰ Bellot, *op. cit.*, (4), 79. Note that professors of philosophy and history were not finally appointed until 1829 and 1833, respectively.

¹¹¹ *The Times*, 26 June 1828, 7a.

¹¹² *The Edinburgh Review*, 47, (1828), 254-5.

¹¹³ *Second Statement*, 18.

¹¹⁴ N. Harte & J. North, *op. cit.*, (70), 46.

¹¹⁵ *Second Statement*, 17.

divided. If, however, the total sum was £100 or less, the professor kept the whole amount.

For the first three sessions, the council guaranteed an income of £300 to each professor in case of low attendance,¹¹⁶ but this was a unique gesture. After this they would be entirely dependent on their fees. While this made chairs in well attended subjects such as mathematics potentially very profitable, it was also expected that "should any of the Classes become so numerous that the Professor alone cannot do justice to his pupils, assistants will be appointed, to be paid by the Professor, without any additional fee from the pupil".¹¹⁷ This presumption was not the only disagreeable clause of a professor's contract. Perhaps the most disturbing was the absence of any security of tenure, since the council had the power to dismiss any of them at will, although they did have the right of appeal. Furthermore, the university's constitution gave the professors no power as a collective body whatsoever, nor the right to be consulted on matters concerning them.¹¹⁸

This did not mean that the professors were not actually consulted. Their collective opinions were sought by the council on many occasions during the period preceding the opening of the university. One of the most important matters concerned equipment for their lecture rooms, with each professor being requested to specify his requirements. De Morgan's were as follows:

Two boxes for containing the Exercises of the Class with openings for slipping papers in, one for the Senior Class one for the Junior and marked accordingly to be placed so that students may conveniently deposit their papers in them on their entrance; but to be moveable so as to be brought down immediately after the Lecture and before the examination of the Pupils commences.

Two pointers, one sufficiently long to reach to the top of the board to be erected, the other about two feet and a half in length.

a reading desk

Inkstand &c

a small frame for notices.¹¹⁹

These preparations heralded the approaching completion of the university building, after an impressively swift construction. Excavation work on the site at the north end of

¹¹⁶ Council Minutes, vol. I, f.187; ULL, MS 322/10, Leonard Horner to De Morgan, 2 Sept. 1828.

¹¹⁷ *Second Statement*, 18.

¹¹⁸ *Statement*, 17-18.

¹¹⁹ UCC, No. 702, De Morgan to Thomas Coates, 11 Oct. 1828.

Gower Street had begun in September 1826, with the laying of the foundation stone taking place in April of the following year. Since then, work had progressed rapidly, with the result that by the summer of 1828, the building was sufficiently advanced for the council to set a date for the formal opening of the university. By the beginning of August, the main structure was substantially complete, although the central portico with its distinctive dome had still to be finished. Several interior features were also incomplete, but the majority of the rooms required for teaching were ready, "and fires will be lighted in them immediately, in order that they may be sufficiently aired for the accommodation of the professors and students by the time appointed for the commencement of studies".¹²⁰ With professors appointed and students rapidly enrolling for the inaugural session, all was now ready for London University to open its doors to the public.

2.2.3 Inauguration

The first lecture at the new institution took place on Wednesday 1 October 1828. It was delivered by the professor of physiology and surgery, Charles Bell, to a public audience "of the highest respectability and very numerous".¹²¹ Bell had presumably been chosen to give this inaugural lecture on account of his public eminence, which certainly ensured ample coverage of opening events in the press. Another reason for the choice was that the medical school opened a month before the rest of the classes, since early October was the time when courses at the other London medical schools usually began. For this reason the academic year of the medical school differed slightly from the rest of the university, running until mid-May; the main university year was to last from the beginning of November until mid-July, with short breaks at Christmas and Easter.¹²²

Bell's initial address was followed during the course of the month by opening speeches from the other medical professors, with introductory lectures in the arts and sciences being delivered from the end of October. These events, which continued well into November, were also well attended and pronounced a great success, with that of Lardner being a particularly triumphant performance.¹²³ Many of the lectures were soon published, or at least received reviews in the daily papers. De Morgan's inaugural lecture, however, seems to have been pretty widely ignored from this point of view, probably

¹²⁰ *The Times*, 6 Aug. 1828, 3e.

¹²¹ *ibid*, 2 Oct. 1828, 3a-b.

¹²² *Statement*, 14.

¹²³ *The Morning Chronicle*, 29 Oct. 1828, 2e; Dionysius Lardner, *A Discourse on the Advantages of Natural Philosophy and Astronomy, as part of a general and professional education. Being an introductory lecture delivered...on the 28th October, 1828*, (London: John Taylor, 1828), iii.

because of the nature of the subject plus his own obscurity. However, the day before its delivery, he was informed that if he had any intention of publication, "it is the wish of the Council that you should previously obtain their sanction".¹²⁴ Whether this, or a possible dissatisfaction with the essay itself, resulted in his decision not to publish, we shall never know. In any case, it exists today only in unedited manuscript form, its only public exposure being on the day of its delivery.

This took place on Wednesday 5 November, precisely five weeks after the university had opened, when, as he later wrote, he "began to teach himself to better purpose than he had been taught, as does every man who is not a fool, when he begins to teach others, let his former teachers have been what they may".¹²⁵ The title of the lecture, according to Sophia De Morgan, was 'On the Study of Mathematics', although this does not appear anywhere on the extant manuscript. Nevertheless, this description, whether correct or not, is an appropriate one, since the text consists, in the main, of a lengthy panegyric to mathematical study. However, it is more than a mere defence of the author's favourite subject, being a thoughtful epistemological essay on mental development and its requirements, written by one who was until recently a student himself.

Indeed, considering the age and inexperience of the author, it is an especially perceptive dissertation, being described as "not only a discourse upon mental education, but upon mind itself".¹²⁶ It also provides us with much information concerning De Morgan's view of his chosen subject and its place in the educational system at the commencement of his professorial career. A short review of the essay will therefore serve to summarise these opinions. Furthermore, an analysis of the arguments employed will illustrate, not only how he chose to defend the study of mathematics, but also what mode of reasoning he used to convince his audience.

The essay begins with an acknowledgement of the exceptional difficulties faced by mathematics compared to most other branches of learning. For example, whereas it would not be difficult to imagine an educated layman deriving some information (or even enjoyment) from a random book on, say, literature, politics or law, it is harder to picture

¹²⁴ ULL, MS 322/12, Leonard Horner to De Morgan, 4 Nov. 1828.

¹²⁵ Augustus De Morgan, "Memorandums on the Descendants of Captain John De Morgan...", University College London Archives, MS. ADD. 7, f.155.

¹²⁶ S. E. De Morgan, *op. cit.*, (13), 29.

the same uninformed person achieving similar fulfilment upon opening a book on mathematics.

What conception can he form of the nature of the information which lays open to his sight? what opinion as to its general utility? what conclusion upon the question whether it would be desirable for him to commence the study? None whatever. The page which lies before him is filled with characters repulsive in their appearance, and conveying no meaning to one not previously acquainted with them. They are in fact to him, a foreign language, a system of hieroglyphics, which there is no more probability of his being able to decypher, than of his reading at first sight, the language of an Arab or Chinese.¹²⁷

This apparent unintelligibility would usually lead, not only to an immediate indifference to the subject and its utility, but also to a disproportionate admiration for those who were mathematically able. De Morgan's object was to show that both attitudes were unfounded.

His argument in favour of mathematical study hinged on the belief that "the success of every individual in the world must depend on his power of *reasoning*".¹²⁸ Moreover, this power was not purely innate, but required a proper education for its adequate development. To this end, it was necessary for the young mind to be provided with a subject whose study would most effectively nurture his reasoning skills. "It is obvious," he said, "that whatever be the subject which is selected as the instrument by which the art of reasoning should be taught to those unaccustomed to demonstration, it should if possible be free from extraneous difficulties, that is from difficulties which are independent of the reasoning itself."¹²⁹ However he noted that, in most of the sciences, these external problems existed, thus distracting the student from the most important matter: the deduction of truths from first principles.

One of these problems was indistinct terminology. Citing an example from Locke's *Essay on Human Understanding*, he gave four similar terms (solidity, resistance, hardness, and impenetrability) which could cause confusion when reasoning: "Here are four expressions, so much alike in their meaning, that in ordinary conversation, they might be used indiscriminately one for the other. Yet there are no two of them which convey

¹²⁷ Augustus De Morgan, "An Introductory Lecture delivered at the Opening of the Mathematical Classes in the University of London, Novr. 5th, 1828", MS. ADD. 3, f.3.

¹²⁸ *ibid*, f.8.

¹²⁹ *ibid*, f.12.

precisely the same idea, and the difference between them cannot be expressed in simple words, so as to leave in the mind of the Student no doubt as to the limits of the meaning of each."¹³⁰ By contrast, however, in the mathematical sciences no terms are exactly synonymous, "and those between which there is most resemblance, can be as clearly distinguished from one another as others which have the most contrary significations".¹³¹

The second difficulty which De Morgan noted was the lack of self-evidence, and sometimes clarity, in the first principles of other sciences. This charge, he claimed, could not be laid against the founding axioms of Euclidean geometry since, for example, no one could be in doubt of the veracity of the claim that the whole is greater than the part, or the precise meaning of the assertion that two figures which entirely coincide with each other are equal. He therefore held that any difficulties the student experienced from the study of geometry "will at least not arise from any ambiguity in the terms to which they are introduced, or any doubt as to the truth of the preliminary propositions which they are required to admit."¹³² Not surprisingly, however, he neglected to mention the most controversial and least self-evident of Euclid's axioms, the parallel postulate.

The final obstacle to accurate reasoning to which he drew attention was the problem of independently confirming the truth of one's conclusions, since, in the experimental sciences, absolute certainty is impossible to achieve. Again, he was able to point out that mathematics does not suffer from this difficulty by showing that complete verification of abstract results could be achieved by constructing alternative proofs using different methods. These independent demonstrations would not only confirm the veracity of the others but would also strengthen the reasoning powers of the student. In short, said De Morgan, since it cultivated the ability to derive new information from known premises, with no empirical doubts as to the nature of its results, mathematics was the ideal tool for the development of reason.

Having given the arguments in favour of mathematics, he then attempted to refute the objections given by opponents of its study. The first of these was that the difficulty of the subject outweighs its utility. Having previously emphasised the benefits of the subject, De Morgan needed only to show that its abstruseness was overrated. He did this by virtue of

¹³⁰ *ibid*, f.16.

¹³¹ *ibid*.

¹³² *ibid*, ff.20-21.

the "childish simplicity [which] reigns throughout its first principles",¹³³ which he had already "demonstrated", and the logical progression of the steps by which each proof proceeds. Thus he claimed that mathematics would pose no greater obstacle to the beginner, than "that which must arise from the novelty of following connected reasoning".¹³⁴

A similar objection to the above was that practical discoveries had been made by those without much, or any, mathematical knowledge. This, De Morgan insisted, in no way weakened his arguments in favour of the utility of mathematics in education; and, even supposing the assertion to be true, "I could not recommend the neglect of these sciences, for your utility will be more extensive, and your fame more certain, if you extend the boundaries of knowledge than if you are merely content with shewing how much can be done without it".¹³⁵ In any case, he contended, it was quite evident that for every benefit to commerce, manufacture, and architecture resulting from natural intelligence, far more would arise from the application of acquired knowledge.

The third argument against mathematical studies was probably the easiest to discredit. This was the dual assertion that they promote an apathy for literature and curb the imagination. The latter objection was easily invalidated with the example of the many and varied attempts given, between the times of Newton and Laplace, to mathematically model all planetary motions to obey the Law of Gravity. The former was, in De Morgan's eyes, equivalent to the claim "that habits of thinking are incompatible with all lighter pursuits, and that Shakespeare and Milton can never be tolerated by any one who is accustomed to arrange his ideas systematically".¹³⁶ This argument was again readily contradicted by the work of mathematicians equally distinguished in other areas of literature. He instanced, amongst others, Plato, Descartes, Pascal, Leibniz and D'Alembert, as examples of mathematicians whose writings "are as distinguished for spirit, taste, and beauty, as their authors are for scientific talent".¹³⁷

Another criticism levelled at mathematicians - and, indeed, scientists in general - was that their subject instilled a disproportionate impression of human power and importance, promoting an arrogance among practitioners. But De Morgan was convinced that

¹³³ *ibid*, f.25.

¹³⁴ *ibid*, f.26.

¹³⁵ *ibid*, f.28.

¹³⁶ *ibid*, f.30-31.

¹³⁷ *ibid*, f.32.

whatever egotism existed among mathematicians could not have resulted from their training in the subject. Indeed, he averred, sufficient mathematical education would actually provide the student with more humility than conceit: "Every one who is acquainted with the mathematics is aware that the higher he advances, the more widely does the horizon open around him, that for one difficulty which he is able to conquer, a hundred remain to baffle his utmost efforts, that ... after all the accumulated labors of three thousand years, in spite of all the brilliant discoveries which have kept alive the admiration of the world, ... the universe of knowledge is as boundless as the universe of matter."¹³⁸

The final comment was really an argument against the *exclusive* study of mathematics. It was asserted that pure mathematical speculation is far too abstract for the real world and does not adequately prepare the student to reason on external matters such as religion, politics or current affairs. De Morgan had no need to refute this objection since he was in complete agreement with it, believing that "the mere study of mathematics alone, is inadequate to make a finished, or even a competent reasoner".¹³⁹ However, forming as it did, a core part of the new university's curriculum, mathematics, if amply supplemented by other academic disciplines, would provide a necessary grounding for courses in natural philosophy and astronomy, as well as being highly beneficial to the study of chemistry, philosophy, jurisprudence and political economy.

When listening to this lecture, several things may have occurred to the audience regarding the educational background of the speaker. Firstly, here was a man who, in addition to a very profound mathematical erudition, had a thorough knowledge of rhetoric and debate, presumably due to his training, brief though it may have been, in the law. Thus, in giving his reasons for promoting the cause of mathematics, he is careful to put forward details of all the opposing views before repudiating them with his own ideas. This also suggests a familiarity with tactics employed by authors such as Aristotle and Thomas Aquinas to refute contrary opinions, which is highly likely considering the breadth of his undergraduate reading. However, his knowledge of such methods is not altogether surprising since, as a mathematician, he would have been perfectly familiar with the concept of *reductio ad absurdum*.

¹³⁸ *ibid*, ff.34-35, 37.

¹³⁹ *ibid*, f.40.

Another predominant trait, again connected with his grounding in metaphysics, is the influence of Kant on his arguments, although he is one of the few philosophers not to be mentioned by name in the essay. This manifests itself in two ways. Firstly, and most obviously, is the importance De Morgan places on logic and reason in the development of intellect. His whole thesis is grounded on the premise that the human mind must learn to reason, for which purpose he argues that mathematics, with its axiomatic structure, is particularly well adapted. Secondary evidence of Kantian influence is also to be found in De Morgan's endorsement of the Euclidean geometrical foundations as a basis for sound reasoning. However, his praise of the clarity and self-evidence of these axioms is perhaps the least convincing section of his argument due to the (possibly deliberate) omission of any reference to the fifth postulate.

In this, as well as other less specific sections of the essay, De Morgan can be quite fairly accused of oversimplifying the subject, almost to the point of distortion. For instance, at one point, when attempting to show that the difficulties of mathematics have been over-exaggerated, he makes the same mistake himself. Citing the example of Newton's *Principia*, which, at the time of its publication was barely understood by the most accomplished mathematicians, he alleged that it "is now read with comparative facility by many who have not attained the age of sixteen".¹⁴⁰ Whether De Morgan himself was reading the *Principia* at the age of fifteen is uncertain, but we do know that even at Cambridge, he was not fully familiar with the whole work, and he was one of the most outstanding mathematicians of his year. The point he is trying to make is obvious, but it is rendered less effective by excessive generalisation.

However, while these slight misrepresentations certainly weakened his argument in several places, it should be remembered that the speech was designed for a lay-audience of non-mathematicians, unacquainted with many of the intricacies and technicalities of the subject. Given also that its purpose was to promote and defend its study, one could hardly expect De Morgan to draw attention to complex mathematical and philosophical issues such as flaws in the foundations of geometry. These limitations to the argument which he was at liberty to present could also provide us with another reason for his decision not to publish the work in this form. Nevertheless, whether or not the lecture convinced those present of the utility of mathematics, it would have left its audience in no

¹⁴⁰ *ibid*, f.26.

doubt of the new professor's devotion to his subject and the ardour with which he intended to teach it.

In line with the council's overall plan for a system of liberal education, the mathematics course which De Morgan had devised was intended to form part of the student's first two years, being divided into classes corresponding to the first and second sessions of undergraduate study. The first year (or junior) course was designed to contain "what is most essential for those who are intended for practical professions, such as Civil Engineers, &c.",¹⁴¹ while the senior class was intended for those capable of tackling more advanced topics, although, due to the range of material available, the course was "confined principally to those parts of the subject which are necessary for the study of Natural Philosophy".¹⁴² However, as can be seen from the following outline, that definition was a very broad one:

JUNIOR CLASS

PLANE GEOMETRY:- The first six Books of Euclid's Elements; algebraical investigations connected with them, particularly with the second and fifth books; connection of the definition of proportion as given by Euclid, with that generally adopted by algebraical writers. Such deductions as will be found useful in the remaining part of the Course; History of the rise and progress of Geometry, with an account and specimens of the geometrical analysis of the ancients.

SOLID GEOMETRY:- Theorems relating to straight lines and planes and their intersections; elements of the geometry of solid angles; the simplest properties of the sphere which bear relation to spherical trigonometry; geometry of the cone, cylinder, and regular polyhedrons; algebraical and trigonometrical applications.

DESCRIPTIVE GEOMETRY:- The simplest elements of this science as far as relates to the straight line and plane; notions on curves of double curvature and the generation of surfaces.

ALGEBRA:- Explanation of algebraical notation; illustrations of its efficacy in solving problems; proofs of the fundamental algebraical and arithmetical operations; simple equations, and problems connected with them; proportion; idea of incommensurable quantities; quadratic equations and problems; permutations and combinations; the binomial theorem; converging series deducible from it; applications of them to the extraction of roots; decomposition of fractions; theory of indeterminate coefficients and applications; arithmetical, geometrical and other simple series; method of estimating the error in approximating to the sum of converging series; philosophical arithmetic, simple properties of numbers; explanation of the decimal and other systems of notation; reduction from one system to another; decimal fractions, finite and circulating; demonstrations of the commercial rules of arithmetic; theory and practice of logarithms; investigation of converging series for the construction of tables; construction and use of

¹⁴¹ *Second Statement*, 42.

¹⁴² *ibid.*

the tables; indeterminate analysis of the first degree; history of the rise and progress of this science.

TRIGONOMETRY, PLANE AND SPHERICAL:- Fundamental principles; relations of the trigonometrical lines; formulæ for the solution of plane and spherical triangles; geometrical applications, particularly to the mensuration of plane and spherical surfaces, and of the solidities of the figures bounded by them; elements of surveying and measurement of heights and distances; description of the simplest instruments used in goniometry; history of this science.

SENIOR CLASS

CONIC SECTIONS:- Principal properties geometrically demonstrated; simplest algebraical and trigonometrical applications.

TRANSCENDENTAL ALGEBRA:- Continued fractions; theory of equations; best methods of approximating to their solutions; applications of trigonometry to this subject; indeterminate analysis; miscellaneous investigations.

THEORY OF PROJECTIONS:- General perspective; linear perspective; projections of the sphere, particularly the stereographic and globular projections, and that of Mercator; elements of dialling; applications of the methods to geometry, particularly to the conic sections.

TRIGONOMETRICAL ANALYSIS:- Analysis of angular sections; developments of the exponential formulæ for the sine and cosine; relations between the small variations of the sides and angles of triangles; principal formula used in geodesical operations.

ALGEBRAIC GEOMETRY:- Geometrical construction of algebraic quantities; elements of geometry of position; determinate problems; classification of curves; the straight line considered as the line of the first order; the conic sections considered as lines of the second order; construction of the solutions of cubic and biquadratic equations; analysis of three dimensions; general principles; the straight line; the plane considered as the surface of the first order; surfaces of the second order, particularly the sphere, cone, and cylinder.

DIFFERENTIAL CALCULUS:- First principles of the theory of limits; rules for differentiation of functions of any number of variables; explanation of partial differentials; theorems of Taylor and Maclaurin; applications of them to the theory of maxima and minima, to the theory of curves and surfaces, particularly to the determination of their tangents and normals and tangent planes, &c, &c.; theory of contact; development of functions in series; elements of the calculus of finite differences; method of interpolation; history of the invention and progress of this science; account of the different methods which have been suggested to remove its difficulties and render it rigorous, particularly that of Lagrange.

INTEGRAL CALCULUS:- Methods of approximating the simplest and most useful functions; method of approximation; applications to rectification, quadrature and determination of solidities; theory of differential equations, and solution of such as are most useful in natural philosophy; integral calculus of finite differences; calculus of variations, solution of problems in it.

THEORY OF PROBABILITIES:- Way of estimating the chances of the happening of an event; solution of simple problems; application to contingencies, such as annuities, insurances, reversions, &c.¹⁴³

As can easily be appreciated from even a cursory glance at this synopsis, De Morgan's new course was a very extensive one. Indeed, considering that the only indispensable preliminary knowledge requisite for entry into the junior class was an acquaintance with the rules of arithmetic, to proceed to a knowledge of the calculus of variations in under two years indicates a very intensive programme of study. However, this outline was intended simply as a overall guide to what students could expect to be taught; more of an indication of what the professor *could* teach than a definite syllabus - a public relations exercise, if you like. It could almost be read as a statement by De Morgan of the range of his mathematical knowledge at the time.¹⁴⁴

In fact De Morgan was at pains to point out that this plan should not be regarded as a definitive declaration of intentions. As he said, "I shall not consider myself bound to carry the class through the whole of what is contained in it if it shall appear that their interest will be more effectually consulted by my confining myself to the more prominent parts of it."¹⁴⁵ Exactly what he *did* teach in his first years as professor is not entirely clear, since no lecture notes (by him or his students) survive from this period. However, it seems very unlikely that he would have been able to cover everything on the above agenda in the time allotted to him. In any case, as far as he was concerned, it was quality of knowledge which mattered more than quantity: "I shall certainly not proceed with any new branch of the subject, until I am thoroughly satisfied that the class has acquired a competent knowledge of the preceding ones."¹⁴⁶

Two areas of the course are particularly intriguing, although they would probably have been among the first to be jettisoned due to lack of time. The first was a consideration of the history and development of the four main mathematical areas: geometry, algebra, trigonometry and calculus. This was no doubt motivated by De Morgan's lifelong love of the history of his subject, in which he was already a specialist by 1828. The second stemmed from his treatment of the progress of the calculus, being an "account of the different methods which have been suggested to remove its difficulties and render it

¹⁴³ *ibid*, 42-45.

¹⁴⁴ Perhaps providing further clues to the extent of his reading while at Cambridge.

¹⁴⁵ A. De Morgan, *op. cit.*, (127), f.45.

¹⁴⁶ *ibid*, f.46.

rigorous, particularly that of Lagrange".¹⁴⁷ This is reminiscent of De Morgan's own undergraduate instruction as seen in his Cambridge notebooks, where accounts of the systems of Newton, Leibniz and Lagrange are all given, with exercises in each. His emphasis on the Lagrangian approach shows the lasting influence of the Analytical Society on his early teaching of the calculus, but it would be interesting to know if the new methods of Cauchy were also mentioned at this time. This is one of the most tantalising aspects of De Morgan's course, but one where, unfortunately, no further information exists.

Despite his almost instinctive mathematical abilities, De Morgan was clearly able to appreciate the difficulties experienced by the average student, being fully aware of the need to eliminate as many barriers as possible to the beginner's understanding of unfamiliar mathematical topics. Nowhere is this better illustrated than in his novel plans for the teaching of geometry. In addition to the requirements stipulated for his lecture room utensils, he had also asked for the provision of various models and equipment to aid with students' visualisation of geometrical problems and concepts. A rough note containing his requests highlighted:

Plane Diagrams (painted)	Regular Solids
Solid Diagrams	Cones with Sections
Sphere	Cylinder with Sections
Joined board for Diagrams	Prisms Pyramids
of Descriptive Geometry	Skeleton Spherical Triangles
Board for Plane Diagrams	Board of Rectangular co-ordinates
Solid Figures	Apparatus for drawing on the Board ¹⁴⁸

He explained his rationale to the audience of his introductory lecture:

Considerable obstacles generally present themselves to the beginner, in studying the elements of Solid Geometry, from the practice which has hitherto uniformly prevailed in this country, of never submitting to the eye of the student, the figures on whose properties he is reasoning, but of drawing perspective representations of them upon a plane. The council of the University with that desire of procuring every thing necessary to the most efficient system of instruction which has distinguished them throughout, has placed at my command, the means of constructing such apparatus, as will be sufficient to remove this difficulty, and I hope that I

¹⁴⁷ *Second Statement*, 45.
¹⁴⁸ ULL, MS 322/9, reverse of Leonard Horner to De Morgan, 8 July 1828.

shall never be obliged to have recourse to a perspective drawing of any figure whose parts are not in the same plane.¹⁴⁹

These then were De Morgan's initial plans and intentions on commencing his duties as professor of mathematics at London University. After over six months of preparation, he not only had a scheme of lectures prepared, but also a methodology by which to deliver them. The next section will discuss the results of this teaching during his first three years in the chair.

2.2.4 Teaching and examination

The number of students attending De Morgan's mathematical classes during the university's first session was 91,¹⁵⁰ rising to 94 the following year.¹⁵¹ Such healthy class numbers would have been very financially rewarding to the young professor. Indeed, with fees levied at £7 for the junior class and £6 for the senior, this put the total receipts during the first session of the mathematical courses at somewhere between £637 and £546. Moreover, given that, at this early stage, most students would have attended the more expensive junior class, we would expect the total revenue to be nearer to this upper bound. This is confirmed by the university's fee register for the opening session which shows the full income to have been £643.¹⁵² Thus, deducting the third of the fees which went to the university fund, De Morgan earned £428 13s 4d during his first year.

The large number of students attending his classes, in addition to improving the professor's finances, also resulted in an increase in his workload, due to the diversity of their mathematical capabilities. It was initially intended that the junior class would meet on Mondays, Wednesdays, Fridays and Saturdays, for an hour and a half each day, with the seniors being taught on Tuesdays, Thursdays and Saturdays, for the same duration¹⁵³ - a total of 10½ hours teaching for De Morgan. However, on meeting his students, he found that the distinction between the juniors and those capable of taking his senior course was not as clearly defined as he had originally thought. Among his pupils he noticed "several whose object is to add a Scientific Education to their former Artificial one, and...while they have obtained sufficient Mathematical Knowledge to proceed

¹⁴⁹ A. De Morgan, *op. cit.*, (127), ff.50-51.

¹⁵⁰ *The Times*, 5 March 1829, 6a.

¹⁵¹ *ibid*, 25 Feb. 1830, 5a.

¹⁵² University of London. Fees Journal. Session 1828-29, ff.7, 13, 22. The extra £6 is explained by a student attending both junior and senior classes.

¹⁵³ *Second Statement*, 10.

without much difficulty with the Senior Class, there are still many subjects in the Junior Course with which they are unacquainted".¹⁵⁴

As a result, when the university opened, his junior class was split into two sections, with one group catering for the above class of student who, since it was largely "composed of older students whose faculties are more developed and whose attention is more particularly directed to the Subject,... will probably proceed somewhat more rapidly and I may be able to direct their attention to some points which I could hardly expect the younger students to understand".¹⁵⁵ By the beginning of 1829, however, further division was needed, this time in the senior class, with the result that by February, De Morgan was teaching a total of 15¼ hours to four separate classes of different aptitudes. His new timetable, displaying in an increase in hours of nearly fifty per cent, was as follows:¹⁵⁶

Junior (First Division):	Mon, Weds, Fri	2.30 - 3.45
	Saturday	11.30 - 1.30
Junior (Second Division):	Mon, Weds, Fri	12.45 - 1.45
	Saturday	11.30 - 1.30
Senior (First Division):	Tues, Thurs	2.00 - 3.15
	Saturday	9.00 - 11.00
Senior (Second Division):	Tues, Thurs	12.45 - 1.45
	Saturday	9.00 - 11.00

Despite this official timetable of "lectures", oral instruction did not entirely dominate De Morgan's teaching, one particular characteristic of his plan of tuition being common to all professors at the university. Since it was universally held that "the efficacy of teaching by Lectures is greatly increased by the practice of examination, it is intended that, *in every class* in the University, the Professor shall devote a certain portion of the hours of instruction in each week to this important duty".¹⁵⁷ De Morgan's aim was to use at least half of the time allotted to him "to examinations both written & oral, and in the Junior Class the proportion will probably be greater."¹⁵⁸ The written examinations were compulsory for anyone intent upon acquiring a certificate, contributing nearly as much to its value as the examinations at the end of the session. They also provided a strong incentive for students to attend all of the lectures, to avoid missing relevant material.

¹⁵⁴ ULL, MS 322/11, De Morgan to Leonard Horner, 26 Oct. 1828.
¹⁵⁵ A. De Morgan, *op. cit.*, (127), ff.52-53.
¹⁵⁶ *University of London. Classes for the Session 1828-9*, (London: Richard Taylor, Feb. 1829), 2.
¹⁵⁷ *Second Statement*, 26.
¹⁵⁸ A. De Morgan, *op. cit.*, (127), f.47.

The oral examinations were designed to serve more as a forum towards the end of the lecture for students to ask questions and discuss any misconceptions arising from preceding material. Participation in these examinations, while not compulsory, was heartily encouraged by De Morgan who would stay at his desk for the best part of an hour to answer further queries from the students. Each lecture would close with De Morgan setting "some exercises for their leisure hours, which will consist mostly of simple deductions from the Theorems which they will find in their Books. From the answers to these, which will be delivered to me in writing at the next meeting of the class, I shall obtain the best materials for future examinations."¹⁵⁹

It was soon realised, however, that the university had no effective way of determining student attendance at these lectures, let alone enforcing it. As early as the end of November 1828, De Morgan, together with the professors of Latin and Greek, sent a memorial to the council arguing that "the system of the University can never be made effective as far as the Junior Pupils are concerned, unless some method be taken to apprise the friends of all such Pupils, of the punctuality of their attendance at the Lectures and the state of preparation in which they usually appear in the Class Room".¹⁶⁰ Their remedy was to "keep a daily account of the attendance, punctuality and state of preparation of each Pupil..., and that printed Reports...be filled up from them, & sent to the Parents or Guardians of every Pupil."¹⁶¹ This recommendation was approved by the council¹⁶² and quickly implemented.

The university's first full examinations took place in March 1829, with end of session papers following in July. An inspection of the questions set by De Morgan in both sets of exams provides the best indication of the material taught during his first session, although the absence of any rubric on the papers means that we do not know how long the students were given to complete the paper (if indeed any definite time was specified), nor the value of each question or how many constituted full marks. However, as De Morgan wrote when he marked the final papers, "I have not made the whole number of marks in the paper any part of my criterion, because it contained fully twice as much as the best could have done in the time."¹⁶³ Thus, since the summer papers contained an average of

¹⁵⁹ *ibid*, f.49.

¹⁶⁰ UCC, No. P167, Professor's Memorial signed by Key, Long and De Morgan, [Nov. 1828]

¹⁶¹ *ibid*.

¹⁶² Council Minutes, vol. I, f.250.

¹⁶³ UCC, No. 1177, De Morgan to Thomas Coates, 3 July 1829.

over sixteen questions, we may deduce that those who correctly answered eight or more could be considered as the high achievers of that year.

In both the Easter and summer examinations, papers for the first division of the junior class concentrated exclusively on the first four Books of Euclid and elementary algebra. As a result, much of the questions relied on reproducing material derived from their books, as is confirmed by the very first question on the March paper, which reads:

Define the words Theorem, Problem, Postulate, Axiom, Parallelogram, and Circle. What axiom may be substituted instead of the last? When is one angle said to be equal to another?¹⁶⁴

Other requirements in geometry included proving Pythagoras' Theorem and describing a regular pentagon in and about a given circle. However, questions on algebra were also in evidence, for instance: "Divide 178 into 3 parts, such, that the third is as great as the other two, and the first and third together fall short of three times the second, by 32."¹⁶⁵ And there was also the occasional mixture of the two, such as "Deduce a geometrical proposition from the following:- $(a + b)(a - b) = a^2 - b^2$ ".¹⁶⁶ The overall performance of students in this class seems to have been adequate, but not outstanding: only nine students received certificates of honour at the end of the session. Nevertheless, De Morgan noted that, considering they had entered the university with no knowledge of either algebra or geometry, he saw "no reason to be dissatisfied with the progress of his junior Pupils".¹⁶⁷

Following De Morgan's earlier prediction, the junior class's second division covered a much wider range of subject matter than its counterpart, and at a swifter pace. This is evident in their examination papers, which required an understanding of the first six Books of Euclid, the theory of equations up to the second degree, logarithms, the binomial theorem, as well as some knowledge of series and plane trigonometry. Students taking these papers were required to prove propositions from Euclid Books 5 and 6 on proportion and similar figures, expand terms such as $\log(1 + x)$ into series, and find the

¹⁶⁴ *University of London. Questions for Examination in the Mathematical Classes. March, 1829. Junior Class - First Division*, Question 1.

¹⁶⁵ *University of London. Mathematical Examination, July 1st, 1829. Junior Class - First Division*, Question 20.

¹⁶⁶ *ibid*, Question 10.

¹⁶⁷ *Distribution of the Prizes and of the Certificates of Honours....Session 1828-1829*, (London: John Taylor, 1829), 6; *The Times*, 10 July 1829, 5c.

angles of a triangle whose sides were given.¹⁶⁸ Yet, despite the supposedly more advanced ability of students in this division, their proficiency (or lack of it) is illustrated by the fact that a mere four of them managed to obtain certificates at the end of the year.

The progress of his senior classes must have been equally frustrating for De Morgan, compounded by a disappointingly low number of attendants. In the lower division only four out of the nine who entered for examination obtained certificates. Their examination papers reveal them to have studied spherical trigonometry ("In every spherical triangle, prove that $\cos c = \cos a \cos b + \sin a \sin b \cos C$ "¹⁶⁹), conic sections ("Prove the properties of the conjugate diameters of conic sections"¹⁷⁰), analytical geometry ("Trace the curve whose equation is $y^3 = x^3 - x^2$ "¹⁷¹), the theory of equations ("Give Cardan's solution of an equation of the third degree"¹⁷²), differential and integral calculus ("Find the area of the curve whose equation is $y = x + (a^2 - x^2)^{-1/2}$ "¹⁷³) and the calculus of finite differences ("Find the successive differences of a^x and $x^3 + x^2 - x$, when the difference of x is unity"¹⁷⁴).

This level of difficulty could certainly compare with material studied by De Morgan in his early years at Cambridge, and in the higher division, the senior class were given the opportunity to proceed even further. Precisely how many of his first year's senior students were able to comprehend these lectures is uncertain, but the number must have been almost negligible since by the summer De Morgan had to report that "the very small number of them who have made this progress, and the departure of some of them from the University, have made an examination of this division of the Class impracticable".¹⁷⁵ It is only by consulting the paper he had set in March (when the class was of sufficient magnitude) that we are able to infer the material taught to this class, which seems to have been, in the main, extensions of earlier work on co-ordinate geometry and calculus, proceeding as far in difficulty as Taylor and Maclaurin's theorems.

¹⁶⁸ Note the similarity to topics covered by De Morgan as a schoolboy in 1822.

¹⁶⁹ *University of London. Questions for Examination in the Mathematical Classes. March, 1829. Senior Class - First Division*, Question 3.

¹⁷⁰ *University of London. Mathematical Examination, July 1st, 1829. Senior Class*, Question 6.

¹⁷¹ *ibid*, Question 8.

¹⁷² *ibid*, Question 11.

¹⁷³ *ibid*, Question 16.

¹⁷⁴ *ibid*, Question 15.

¹⁷⁵ *op. cit.*, (167).

The experiences of De Morgan and his fellow professors during their first year at the university resulted in a few changes, not only in the courses they taught, but also to the rules of the institution itself. During the first session, no fewer than thirty students had been under fifteen years old, with two being aged only eleven.¹⁷⁶ Possibly due to their immaturity, both in attitude and academic preparation, one of the main alterations to the regulations by the beginning of the second session was the institution of a minimum age limit, it being recommended "that no person should enter who is under fifteen years of age".¹⁷⁷ Ironically, one of the most troublesome of these juveniles, whose behaviour may have been in some degree responsible for the new policy, had also distinguished himself as one of the most talented mathematical students De Morgan would ever teach.

James Joseph Sylvester (1814-1897) would eventually become one of the foremost British mathematicians of the nineteenth century and was to contribute to the advancement of the subject in many key areas. Born in London on 3 September 1814 to a prosperous middle class Jewish family, he was admitted as a student of the university in November 1828, aged just fourteen. He immediately entered the higher division of De Morgan's senior class "and became by far the first pupil in it",¹⁷⁸ distinguishing himself "by the facility with which he acquired a knowledge of the higher branches of Mathematics & the singularity of his power to apply them."¹⁷⁹ Indeed, so impressed was De Morgan by his remarkable young student that he later went on record to say "that he never, before or since, saw mathematical talent so strongly marked in a boy of that age".¹⁸⁰

However, outstanding though his mathematical talents undoubtedly were, Sylvester's general demeanour left much to be desired. Reports sent to his sister (in whose care he was at the time) concerning his conduct and attendance complained "of his inattention to his duties".¹⁸¹ He was also apparently "of a most impetuous and irritable disposition, and his extreme youth, together with his religion, reputation for talent, and the disposition above-mentioned, made him, it is supposed, a mark for the practical jokes of his fellow

¹⁷⁶ University of London. Register of Students, vol. I, ff. 21, 63.

¹⁷⁷ *University of London. Notice of the Courses of Lectures during the Session 1829-1830*, (London: Richard Taylor, 1829), 2-3.

¹⁷⁸ UCC, No. AM/7, Committee Report on the appointment to the chair of natural philosophy, 18 Nov. 1837, f.3.

¹⁷⁹ UCC, Testimonial from De Morgan, [May 1841].

¹⁸⁰ *op. cit.*, (178), f.3.

¹⁸¹ UCC, No. 1614, Letter from E. J. Sylvester, 9 Feb. [1829].

students".¹⁸² A consequence of this taunting, combined with the boy's volatile temper, led to the display of "so great a disposition to an act of violence that his friends were advised by the authorities of the College to remove him: which was accordingly done."¹⁸³

A clue to what form this violent behaviour took lies in an extract from a letter, formerly in the archives of University College, written by Thomas Hewitt Key, which stated that: "The accompanying knife has just been taken from young Sylvester, who had brought it from the Refreshment rooms for the purpose of stabbing Mr. Tulk".¹⁸⁴ This event, cited in Bellot's history and elsewhere, led to the myth that Sylvester was one of the first students to be expelled from the university. But a letter from his sister, written at the end of February 1829, reveals that Sylvester's family had already come to the conclusion that "owing to the extreme youth of my Brother and the fact of his requiring constant control and attention they deem it advisable that he should for the present withdraw from the London University".¹⁸⁵ He was to return to Gower Street eight years later under very different circumstances, and not as a student. But despite the brevity of his studies in London, he remained proud of the four months he had spent under the tutelage of De Morgan, "whose pupil," he later recalled, "I may boast to have been".¹⁸⁶

Following his over-estimation of student abilities in the opening year, the syllabus De Morgan set out at the beginning of the 1829-30 session was a far more modest proposal. While the entrance requirements for the first division of the junior class remained the same, lectures were entirely excluded from their tuition, with instruction consisting "entirely of examination in Euclid, and practice in the operations of Algebra".¹⁸⁷ As to what the second division could expect to be taught, he could be no more specific than to announce that the subjects would be "on such of the more advanced branches as the Pupils are prepared for".¹⁸⁸ For the senior classes, it would seem that he used the amount of material covered in the preceding year as his guide, since his revised list of subjects to be pursued was "Spherical Trigonometry, Conic Sections, the Theory of Equations, the application of Algebra to Geometry, &c."¹⁸⁹

¹⁸² *op. cit.*, (178), f.4.

¹⁸³ *ibid.*

¹⁸⁴ This letter is now missing from the archives, but the card catalogue preserves this extract.

¹⁸⁵ UCC, No. 1615, Letter from E. J. Sylvester, 25 Feb. 1829.

¹⁸⁶ James Joseph Sylvester, On Derivation of Coexistence, Part II. Being the theory of simultaneous simple homogeneous equations, *Philosophical Magazine*, (3), **16**, (1840), 37-43, p.43 note.

¹⁸⁷ *op. cit.*, (177), 7.

¹⁸⁸ *ibid.*

¹⁸⁹ *ibid.*, 8.

In addition to his revised course outline, De Morgan also took the opportunity to ensure that students' knowledge of previous material was maintained, by running classes where both divisions would be taught together:

Junior (First and Second Divisions):	Mon, Weds, Fri	9.15 - 10.30
	Saturday	9.00 - 10.30
Junior (Second Division):	Tues, Thurs	9.15 - 10.30
Senior (First and Second Divisions):	Mon, Weds, Fri	2.15 - 3.15
	Saturday	11.00 - 12.30
Senior (Second Division):	Tues, Thurs	2.15 - 3.15

Though it is unlikely to have been motivated by a desire for a diminution in workload, this new timetable reduced his teaching by one hour. His fees remained the same.

As a result of these more realistic expectations, the progress made by De Morgan's students in his second and third sessions was far more impressive than in the first. However, his new approach was not the only explanation for the improvement. In 1828, his students had all come from a wide variety of educational backgrounds with hugely disparate standards of mathematical knowledge. By 1829, following a year of De Morgan's tuition and examinations, most of them had a more uniform level of mathematical attainment. Consequently, he found that "the state of preparation of the generality of Students, at the commencement of the present Session, was much superior to that of the last",¹⁹⁰ with many being capable of progressing to a higher class or division.

His higher senior class now had a sufficient number of students to warrant examination. Moreover, by the end of the 1829-30 session, his tuition in that division had advanced to such topics as "the application of Algebra to Geometry of three Dimensions; the Differential and Integral Calculus, including the Integration of Differential Equations, and its applications to the Theory of Curves and Surfaces".¹⁹¹ A year later, it extended to "the Theory of Projections, and the Elements of Descriptive Geometry".¹⁹² The second

¹⁹⁰ *University of London. Distribution of the Prizes and of the Certificates of Honours....Session 1829-1830*, (London: John Taylor, 1830), 32.
¹⁹¹ *ibid.*
¹⁹² *University of London. Distribution of the Prizes and Certificates of Honours....Session 1830-1831*, (London: George Woodfall, 1831), 25.

division of the junior class also made substantial improvements on their initial progress with the additional study of continued fractions, first degree indeterminate equations, solid geometry and spherical trigonometry. Encouraged by these developments, De Morgan advised Horner that no changes in his mode or course of instruction would be required for the 1830-31 session, "being perfectly satisfied with the manner in which they have worked".¹⁹³

As with his undergraduate course at Cambridge, De Morgan's London University syllabus is similarly vague with regard to reading, providing us with very little information as to the books he recommended for the use of his students. In fact the only book to be explicitly mentioned is Lardner's edition of Euclid, although there would almost certainly have been other books used. However, it seems that from an early stage De Morgan was keen to use material prepared by him, specifically designed for the use of his students. The first step in this direction was his very first published work, a translation of the first three chapters of the French textbook *Elémens d'Algèbre* by Pierre Bourdon, which appeared in 1828. This was followed two years later by *The Elements of Arithmetic*, the first of many textbooks he was to produce in his own right, and certainly the most successful, as can be ascertained from comments written towards the latter half of the nineteenth century:

Forty years have elapsed since the appearance of Prof. De Morgan's *Elements of Arithmetic* at a time when perhaps few teachers, as they submitted the rules of science to their pupils, cared to establish them upon reason for demonstration. The effect of this work was that a rational arithmetic began to be taught generally, and the mere committing of rules to memory took its subordinate position in the course of instruction.¹⁹⁴

In 1830 appeared the first edition of the well-known *Elements of Arithmetic*, which has been widely used in schools, and has done much to raise the character of elementary training. It is distinguished by a simple yet thoroughly philosophical treatment of the ideas of number and magnitude, as well as by the introduction of new abbreviated processes of computation, to which De Morgan always attributed much practical importance. Second and third editions were called for in 1832 and 1835,

¹⁹³ UCC, No. P113, De Morgan to Leonard Horner, 6 July 1830.

¹⁹⁴ Adolf Sonnenschein and Henry Arthur Nesbitt, *The Science and Art of Arithmetic for the Use of Schools*, Parts II and III, (London: Whittaker and Co., 1870), iii.

and more than 20,000 copies have been sold; the book is still widely in use, a sixth edition having been issued in 1876.¹⁹⁵

This was the start of De Morgan's career as a teacher, both in the lecture room and on the printed page. It was certainly a solid beginning, although not a spectacular one. However, his achievements are all the more impressive when it is recalled, firstly, that he was still very young; secondly, that any course of study at the new university was, by its innovatory nature, experimental and uncertain of success; and finally, that he, in common with all of his fellow professors, was forced to operate in increasingly unpleasant circumstances due to organisational difficulties and numerous petty disputes which beset the institution within months of its opening.

2.3 Disappointment

2.3.1 Problems

One of the most pressing of these early difficulties was money. The only sources of finance at this time were shares and fees, with the council grossly over-spending income derived from the former and wildly over-estimating the revenue likely to be obtained from the latter. The majority of their initial capital had been lavishly consumed on the university building with the expectation of substantial recoupment from a healthy number of students. A figure of 2,000 was mentioned at one point,¹⁹⁶ although 1,100 would have been sufficient to balance the books. However, these hopes were quickly dashed when a disappointingly low total of 641 students registered during the first year.¹⁹⁷ This number fell to 630 in the following session, causing the council considerable concern, and puzzlement:

Notwithstanding the publicity that has been given by extensive advertisements, it is very remarkable how little more than the mere existence of the University is yet known to the people of London, even to those who reside in its vicinity; and in the country it is still less known. ... When the public are fully aware of the excellence and cheapness of the education and the facility of admission, there can be little doubt that such advantages will not be neglected.¹⁹⁸

¹⁹⁵ William Stanley Jevons, De Morgan, *Encyclopædia Britannica*, 11th edition, (Cambridge: Cambridge University Press, 1910), 8, 8-10, p.8.

¹⁹⁶ *Statement*, 26.

¹⁹⁷ This number was originally believed to be 624, but has recently been re-calculated.

¹⁹⁸ *The Times*, 25 Feb. 1830, 5a.

Yet, despite these sanguine hopes, the student population continued to fall and the resulting lack of income forced the council to abandon its policy of guaranteeing an income to its professors. This obviously had a serious effect on those whose classes were not numerous, such as Dionysius Lardner. Due to the necessity of some mathematical knowledge for the study of natural philosophy, "no regular Class of academical Students presented themselves in this science" during the university's opening session, resulting in the need to "adapt the Lectures principally to Students whose knowledge of elementary mathematics was very limited".¹⁹⁹ When the session 1829-30 yielded no tangible improvement in his class sizes, Lardner became increasingly concerned, especially since he had previously been assured by Brougham that his fees might be as high as £1,200.²⁰⁰ The council attempted to allay his anxiety:

The Council expect that there will be a considerable increase of the Students in your Classes next year, when they take into account that your reputation as an able teacher is considerably extended, that your power of illustration by a very fine Apparatus is more known, and that a large proportion of the Students of the first Session will by that time be prepared by previous study under Mr De Morgan to enter with advantage the Classes of Natural Philosophy.²⁰¹

Lardner's misgivings were not alleviated by the fact that, while he and the other professors had to rely on an unpredictable income of fluctuating fees, Leonard Horner as the university's Warden was receiving an annual *salary* of £1,200. Moreover, this was happening at precisely the same time that the council was withdrawing professorial guarantees on the grounds of diminished income. But the Warden's generous allowance was far from being the only source of irritation to the professors. The situation was highly aggravated by the arrogant and high-handed attitude adopted by Horner in this post and the pedantic manner in which he interfered in their affairs. Moreover, members of the ruling council proved themselves to be strangely unsuited to the adequate management of their employees, being "either liberal politicians, not always familiar with the details of academical discipline, or mercantile men, who, with the best possible intentions, had no experience of the best way of securing concord and due balance in the relations of governing body, teacher, and pupil".²⁰²

¹⁹⁹ *Distribution of the Prizes and of the Certificates of Honours....Session 1828-1829*, (London: John Taylor, 1829), 7.

²⁰⁰ Bellot, *op. cit.*, (4), 175.

²⁰¹ ULL, MS 322/23, Leonard Horner to Dionysius Lardner, 19 Jan. 1830.

²⁰² S. E. De Morgan, *op. cit.*, (13), 26.

In addition to the dictatorial and inconsiderate nature of the ruling body and its chief officer, the professors' problems were compounded by a Deed of Settlement in which they were explicitly denied any collective rights whatsoever. Indeed, unlike the regular students, professors were not even officially members of the university, being regarded by the council as no more entitled to privileged status than the doorkeepers, caretakers, or any other of its employees. Furthermore, the refusal to allow the formation of faculties or departments gave them no statutory mode of registering approval or disapproval of decisions affecting them. This combination of "a defective constitution, a tactless Warden, an autocratic, peremptory, and parsimonious Council, and a vacillating policy"²⁰³ was to prove almost fatal to the survival of the new institution.

But it was the attitude of the council's emissary, more than its unfavourable decisions, which was the initial cause of ill feeling among the teaching staff of the university. By a cumulative combination of an exalted view of his own importance and continued unwarranted intervention in their dealings with the council, Horner, initially regarded merely as an irritating message-bearer by the professors, was soon seen as an antagonistic and bitter enemy with his own agenda and interests hugely at variance with their own. It was inevitable that disagreements would regularly arise between him and the academic staff, and, midway through the second session, the professor of mathematics was drawn into the debate.

His argument with Horner, trivial as it may now appear, serves as an excellent illustration of the myriad of similar petty quarrels which plagued the university in its opening years. The cause of the dispute was De Morgan's (not insubstantial) concern about the state of discipline in his class room, summarised in the following letter to the Warden:²⁰⁴

Dear Sir,

I find myself obliged, as I stated to you this morning, to bring before the Council the state of my class room with respect to order and silence, or rather the want of them, in which I must request their assistance. In consequence of the nature of my Lectures my back must be turned from the students or some of them at least, during a great part of the Lecture. This inconvenience I can manage to prevent from causing any

²⁰³ Bellot, *op. cit.*, (4), 190.

²⁰⁴ UCC, No. P106, De Morgan to Leonard Horner, 12 March 1830.

disturbance in my own Lecture Room but since I have found it necessary to use a Room filled with tables instead of benches, the difficulty of detecting the authors of disturbance has become so much greater that I do not see how to remedy it except by increasing the penalty and making it more imposing. This morning, after I had addressed the class and told them that I should certainly take measures for the removal of any one whom I might detect talking &c, within the space of five minutes I discovered a direct instance of contempt of all I had said shewn by a student of the name of Hyde who has during this Session and the last been among the most disorderly of my class. I ordered him to quit the Room, telling him at the same time that I should make a communication to the Council on the subject. In such a case I should recommend that a formal notice should be sent to his friends, informing them that for the next offence he should be expelled not only from the class but from the University and that this notice should be strictly acted up to on the first occurrence of it.

Should the Council take the same view of the subject, this notice should be forwarded as soon as possible and the effect would be greater, since the subject would be better known among the Class, if a copy of it were given to the Individual himself. The subject is of greater importance, as I begin to be convinced that the efficiency of my instruction is much lessened by the constant watch which I am obliged to keep guard against disturbance. I am convinced we want some form of proceeding in such cases, which may be common to all Junior Classes, and known by the Students,

I am

Dear Sir

Yours truly

Augustus De Morgan

University

March 12th 1830

Horner's reply, while polite and no doubt written with the best of intentions, sowed the seeds of an immediate disagreement. He wrote: "The Council leave the maintenance of discipline to the Professors and myself and I do not consider it necessary to go to them for instructions. I have no hesitation in authorising you to use the threat of expulsion if your pupils disregard your admonitions; and if you think that I can assist you by throwing

in any more form into the proceeding I am quite ready to do so."²⁰⁵ This letter would have been extremely disturbing to any professor since Horner had clearly acted independently of the council, assuming powers of authority over the professors to which he was not entitled. De Morgan's immediate response was to ask: "What am I to understand by the following words 'I have no hesitation in *authorising you* to use the threat of expulsion' &c which are used in your letter to me of the 12th instant".²⁰⁶ The result was a barrage of correspondence between the two men in which all reference to the initial problem of student discipline was forgotten amid the increasingly heated dispute as to whether Horner had overstepped his bounds as Warden.

In consequence, a petition was signed by eleven of the professors, including De Morgan, complaining of an abuse of position by Horner and requesting "that the Council will make the Warden acquainted with the nature of the situation which he holds in the University".²⁰⁷ In June, it was agreed that an emergency meeting should be held "to consider the state of the University as regards the differences existing between the Council and the professors, [and] the duties of the office of Warden",²⁰⁸ as a result of which the professors were left in no doubt with whom the council's sympathy lay. As Olinthus Gregory said, in a letter to Brougham, although he "deeply deplored the painful discussions between the Warden and several of the Professors..., when I have meditated upon the admirable prudence and judgment of Mr. Horner, although I may have thought him guilty of two or three mistakes in minor points, I have in the main regarded his conduct as correct".²⁰⁹

Horner was now bitterly unpopular with the majority of the professoriate, not only for his petty attempts to promote his own interests, but for the ludicrously extravagant salary which he still insisted on receiving, while their wages could no longer be guaranteed. This resentment was not improved when a plan of financial retrenchment drawn up by a section of the professoriate,²¹⁰ involving the abolition of the office of Warden, was

²⁰⁵ UCC, No. 3350d, Leonard Horner to De Morgan, 12 March 1830.

²⁰⁶ UCC, No. P107, De Morgan to Leonard Horner, 13 March 1830.

²⁰⁷ UCC, No. 3350d, Professors' Memorial, signed by Conolly, Davis, De Morgan, Galiano, Key, Lardner, Long, McCulloch, Pattison, Rosen, Mühlenfels, 25 March 1830.

²⁰⁸ Council Minutes, vol. II, f.98.

²⁰⁹ University College London Archives: Brougham Correspondence, No. 28,608, Olinthus Gregory to Lord Brougham, 3 Dec. 1830.

²¹⁰ *A letter to the shareholders and Council of the University of London on the present state of that Institution*, (London: Thomas Davison, 1830); UCC, No. 3350f, Professors' Memorial, signed by Conolly, Davis, De Morgan, Galiano, Lardner, Long, McCulloch, Pattison, Mühlenfels, [20 May 1830].

rejected by the council. With the council's inept management of the affair, the university's internal disputes quickly became public knowledge²¹¹ as "the conflict between the Warden and the professors was allowed to become an open war of pamphlets and newspaper paragraphs".²¹²

Eventually, Horner's position became untenable and, in March 1831, he tendered his resignation, effective from the end of the session. His grounds for withdrawal included deprivation "of that influence and authority which are implied in the very title of the office, which it was understood he should possess when he accepted it, ...doubts which have been raised on several occasions as to his possessing that degree of discretionary power which he holds to be inseparable from such an office,...and that, without any means of protection, he is liable to be addressed, and to have his conduct and motives called in question by members of Council at Board, in a manner which no gentleman ought to tolerate."²¹³ His resignation was accepted, the office of Warden was abolished, and a secretary employed on an annual salary of £200 in his place.²¹⁴

Horner's resignation was not the first premature departure the university had seen in these months, nor was it to be the last. Inadequate emoluments, in addition to the recent unpleasantness, had caused the resignation of Thomas Dale from the professorship of English in 1830, followed by Galiano in the chair of Spanish. Further resignations were to come, although these were due to yet another controversy, which this time had not been initiated by the Warden, although he still played a major role in its development. This final dispute was arguably the most involved and acrimonious in the university's history, almost resulting in the closure of the institution itself. It would also have a momentous impact on the course of De Morgan's career.

2.3.2 Resignation

The central figure in the row was the professor of anatomy, Granville Sharp Pattison, its initial cause being dissatisfaction, among a portion of his students, with the tuition he gave. Complaints had been received by the council on two occasions during the first

²¹¹ *The Times*, 5 July 1830, 3c.

²¹² Bellot, *op. cit.*, (4), 202.

²¹³ *The Times*, 13 April 1831, 3c.

²¹⁴ Horner went on to achieve distinction as one of the first chief inspectors of factories from 1833 to 1856, an enterprise which he undertook with characteristic enthusiasm and vigour. His replacement as the university's secretary was Thomas Coates, who had been secretary of the SDUK since 1826. He was succeeded in 1835 by Charles Caleb Atkinson, who served until 1867.

session, and with increasing regularity thereafter. These objections charged Pattison with ignorance, incompetence and a neglect of his duties. It was alleged that he even used to appear for his lectures in a pink coat and riding boots. The protests reached a zenith in 1830 with students calling for his dismissal on the grounds of "*unusual ignorance* of old notions, and *total ignorance of* and *disgusting indifference* to new anatomical views and researches ... he is ignorant, or, if not ignorant, indolent, careless, and slovenly, and, above all, indifferent to the interests of the science".²¹⁵

There is little doubt that Pattison was not a good teacher. Neither did he attempt to court popularity with his students, deliberately rejecting the more modern 'French anatomy' in favour of a more old-fashioned approach: but these were not in themselves grounds for censure. Furthermore, a committee appointed by the council to investigate the charges of idleness could find no evidence for these claims and ruled in the professor's favour.²¹⁶ Not surprisingly, the students remained dissatisfied and the problem remained unsolved. Tension was further heightened by three other factors: firstly, the prevailing atmosphere of malaise and mistrust which had permeated the university by this time; secondly, the unusually suspicious and quarrelsome nature of Pattison himself; and thirdly, the presence of an independent demonstrator of anatomy, James Bennett.

From the outset, Pattison had regarded the appointment of Bennett as an insult to his reputation and authority. Furthermore, with Bennett's delivery of a separate course of lectures on anatomy, Pattison also found his financial position impaired. When it also transpired that Bennett was a far better, and therefore more popular, lecturer, Pattison's jealousy became manifest. So too, however, did the scorn felt by Bennett for his colleague's blatantly inferior abilities, which he took no pains to conceal from the students. Concern for the reputation of the medical school was also voiced by Charles Bell, who shared Bennett's opinion of Pattison's incompetence. This intervention activated Pattison's keen sense of paranoia, since Bell was a close friend of Leonard Horner, who he saw as the chief architect behind the student disquiet.

Pattison's labelling of Horner as the villain of the piece certainly won him the support of many of his colleagues who may, objectively, have held a very different opinion. However, while there was no love lost between the Warden and the professor of

²¹⁵ Bellot, *op. cit.*, (4), 197-198.

²¹⁶ Granville Sharp Pattison, *Professor Pattison's statement of the facts of his connexion with the University of London*, (London: Longman, Rees, Orme, Brown, and Green, 1831), 11.

mathematics by this time, the latter's view on the subject does not appear to have been motivated by malice to the former. De Morgan's opinion seems to have been grounded on the fundamental principle that a professor was always right, by definition. Moreover, he believed that students, by their very nature, were unfit to determine the ability of someone better qualified than they. His argument was that if the students had the power to disrupt classes and cause a professor's dismissal merely because they did not like him, it was they, and not the council, who ruled the university. In any case, he asked, "what gentleman of education would submit to be bearded by his pupils?"²¹⁷

By the beginning of the 1830-31 session, agitation amongst the medical students had brought chaos to much of the university. Pattison's lectures were boycotted, or prone to frequent interruption and disturbance.²¹⁸ By February 1831, it was impossible for him to lecture without being shouted down by his opponents. A new committee was appointed by the council to consider the matter. Their report, inconclusive though it was, resulted in a recommendation that the only way to restore order among the students was to remove Pattison from his post. This immediately resulted in a memorial signed by De Morgan, Key, Long, Lardner, McCulloch and Rosen protesting that the proposal was an injustice to their colleague and expressing concern about the implications for their own positions.

They attributed blame for the recent disturbances, not to any flaw in Pattison's conduct, but to the disrespectful attitude of the students and the absence of an efficient system of discipline. "There is no University in the World," they argued, "where it would be for a moment tolerated that the Students should have any constraint direct or indirect over the appointment or removal of a Professor".²¹⁹ In any case, they insisted, no charge of incompetence had been established against Pattison and "[e]xpediency alone, if we are rightly informed, is the ground of the contemplated measure".²²⁰ They served notice that they would regard a decision by the council to dismiss Pattison as "a declaration that the office of Professor is one held from year to year upon the suffrage of the fluctuating body of Students. ...Such a measure...would render the situation of a Professor in the University not to be envied by any individual who knows the value of self respect."²²¹

²¹⁷ *The Times*, 22 August 1831, 6d.

²¹⁸ Pattison, *op. cit.*, (216), 18-19.

²¹⁹ ULL, MS 322/52, Professors' Memorial, signed by De Morgan, Key, Long, Lardner, McCulloch and Rosen, [May 1831].

²²⁰ *ibid.*

²²¹ *ibid.*

A natural consequence of these opinions, for De Morgan at least, was a letter to the council in which he conditionally tendered his resignation, subject to their decision on the Pattison affair. This letter concluded:

Having announced my intention, I am therefore in the hands of the Council; should they consider it unfair in me to offer a conditional resignation dependent on circumstances over which they have no control, I will, on intimation to that effect, offer an absolute resignation immediately. My wish is decidedly to remain in the University, if that can be done consistently with my own notions of what is due to my character. Having thus shortly stated the predicament in which I find myself placed, I leave the matter to the decision of the Council.²²²

The council were thus in the dilemma of facing continued student insurrection, or sacking a professor and risking the resignation of at least one more as a result. Their options were considerably restricted since their constitution gave them no jurisdiction over student behaviour. Given also that prolonged unrest would be disastrous for their public image, especially when it is remembered that the university's finances were in a very delicate state, there was really no alternative but to force Pattison to leave. This they did in a resolution passed on 23 July 1831, to the effect "that the popularity and efficiency of the medical school have received a shock by the disturbances which have prevailed in it, and which can only be obviated by the retirement of Professor Pattison".²²³ Four days later, they received the following letter:²²⁴

Gentlemen,

I have just seen Mr Pattison, who has informed me of his removal from his Chair, and has shewn me a resolution of which this is a copy

"Resolved, that in taking this step the Council feel it due to Professor Pattison to state, that nothing which has come to their knowledge with respect to his conduct has in any way tended to impeach either his general character or professional skill and knowledge."

²²² UCC, No. 2470, De Morgan to the Chairman of the Council, 9 July 1831.

²²³ Council Minutes, vol. II, f.308; *The Times*, 25 July 1831, 3e.

²²⁴ *ibid*, f.310.

Here is distinctly laid down the principle that a professor may be removed, and as far as you can do it, disgraced, without any fault of his own.

This being understood, I should think it discreditable to hold a Professorship under you one moment longer.

I have therefore the honor to resign my Professorship and to remain

Gentlemen

Your obedient servant

Augustus De Morgan²²⁵

90 Guilford Street

Sunday July 24th 1831

His resignation was immediately accepted,²²⁶ being followed in August by those of Long²²⁷ and Rosen.²²⁸ All three erstwhile professors now faced the uncertain prospect of finding alternative employment - although it is interesting to note that they would all, at various points in the future, return to the university.²²⁹ Ironically, of all the displaced academics, the affair seems to have had the least adverse effect on Pattison, who received a grant of £200 and immediately returned to the United States to take the professorship of anatomy at the Jefferson Medical College, Philadelphia. He stayed there until 1840 when he accepted a similar post at the University of New York, which he held until his death in 1851.

The position in which Augustus De Morgan now found himself was an unusual one. At the age of only twenty-five, he had rejected the only chance he was likely to have of academic employment. Once again his strong principles had resulted in a decision which left him facing an uncertain future. Yet with the university experiencing a rapid decline in both its finances and public confidence, there was every reason for him to think that had he remained, his prospects would have been equally insecure. Indeed, the next five years were to be a period of intense upheaval and uncertainty for the university, involving numerous changes both to the professoriate and its constitution. Yet by the end of this period, circumstances at London University would be far more conducive to academic

²²⁵ ULL, AL 45/1, De Morgan to Council, 24 July 1831.

²²⁶ Council Minutes, vol. II, f.310; ULL, AL 45/2, Thomas Coates to De Morgan, 27 July 1831.

²²⁷ *ibid*, f.321.

²²⁸ Committee of Management Minutes, vol. I, f.10.

²²⁹ Long as professor of Latin, 1842-46; Rosen as professor of Sanskrit, 1835-37; and De Morgan...to be seen in the next chapter.

confidence than at any previous time in its brief history. The process by which this came about will be discussed in the next chapter, along with how mathematics was taught in De Morgan's absence; his work during this time; and the reasons for his eventual return.

Chapter 3

The White Period, 1831-1836

3.1 A Professor without a Chair

For the historian today, the period between De Morgan's resignation in 1831 and his reinstatement five years later is one of considerable uncertainty. In matters regarding the university, details concerning mathematical tuition become increasingly obscure. Little biographical information relating to the new professor of mathematics is available and documents connected with his teaching are particularly vague and confused. Yet despite this, some idea can still be formed of the events surrounding the new appointment and his subsequent work in mathematical education, as section 3.2 will show. Details concerning De Morgan's own career during his time away from the university are similarly evasive. He was certainly academically active during this period, yet very little information can be derived on precisely how he managed to support himself in the absence of professorial emoluments at this time. This section will attempt to clarify this question as well as providing an overview of his activities during this period.

Following his rejection of both a respectable position and a reliable source of income, De Morgan now had to find other means of financial provision. A possibility would have been to return to Lincoln's Inn in order to qualify as a lawyer, but his previous experience must have proved discouraging since there is no evidence that he ever considered the prospect. It would seem, in fact, that having enjoyed using his mathematical expertise to earn a living, De Morgan was determined to find alternative methods of continuing to do so. Hence, in 1832, we find that he applied for the vacant post of actuary at the Amicable Assurance Office.¹ Although well qualified for the position, which was a lucrative one, he was ultimately unsuccessful. But, as his wife tells us, "he would not have liked the work so well as he did teaching and writing, and he had, as he afterwards told me, but one reason for wishing to succeed".² The successful candidate was his friend Thomas

¹ The same firm which had denied his great-grandfather a policy 77 years previously.

² Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, and Co., 1882), 60. This one reason was, presumably, financial.

Galloway (1796-1851), who, until his appointment, had been teaching mathematics at the Royal Military College in Sandhurst.³

It was hardly surprising that De Morgan should choose to seek employment as an actuary since - even disregarding the precedent of his distinguished forebear - as a mathematician, such a post would have been well suited to his abilities as well as financially rewarding. He was no doubt assisted in his efforts by William Frend, who from 1806 to 1827 had been actuary for the Rock Life Assurance Office⁴ and presumably still had contacts in the profession. We are told in fact that he "opened to De Morgan a fresh sphere of labour, in which he turned his mathematical acquirements to account in the service of many of the London Insurance Companies".⁵ The actuarial profession may have been a new branch of mathematical employment during the time of Dodson, but it was still in its infancy a century later. Consequently, men like Frend and De Morgan, who were able mathematicians with an understanding of actuarial methods, had the potential to follow very lucrative careers in the insurance business.

It would seem that this is what De Morgan did, both before and after his return to the university, ensuring an increased revenue by acting as a freelance consultant to a variety of companies. We are told that as an actuary "he occupied the first place, though he was not directly associated with any particular office; but his opinion was sought for by professional actuaries on all sides, on the more difficult questions connected with the theory of probabilities, as applied to life-contingencies".⁶ In addition, he also wrote an *Essay on Probabilities and on their application to life contingencies and insurance offices*, which appeared as part of Dionysius Lardner's *Cabinet Cyclopædia* series in 1838 and remained highly regarded in insurance literature for well over a generation.

His other chief source of income appears to have been from private pupils which, at the time of his resignation, he certainly believed could be a very profitable business, since "I know that by my own private exertions I can gain as much as...I have ever done in my

³ It is interesting to note that, at the time of his appointment, Galloway was one of three shortlisted candidates for the professorship of natural philosophy at Edinburgh University (vacated by the death of Sir John Leslie in 1832). Although pure speculation, it is certainly possible that, had he received that chair and De Morgan had become a full-time actuary, the latter might never have returned to university tuition at all.

⁴ *The Gentleman's Magazine*, **15** (1841), 541-3, p.543.

⁵ Arthur Cowper Ranyard, Obituary notice of Augustus De Morgan, *Monthly Notices of the Royal Astronomical Society*, **32** (1871-72), 112-118, p.114.

⁶ *ibid*, 116.

public capacity".⁷ This confidence seems to have been justified, since private tuition apparently occupied a great deal of his time during this period. The identity of the great majority of his pupils is, not surprisingly, unrecorded. However, two names are known to us. The first, Jacob Waley (1818-1873), another extremely gifted mathematical student of Jewish extraction, would later achieve great distinction in De Morgan's college classes on his return.⁸ Yet he also received individual tuition from his future professor, being "a diligent private pupil and...a valued friend [whose] lessons at our house in Gower Street were pleasant to both teacher and pupil".⁹ De Morgan's other identifiable pupil, better remembered for her friendship with Charles Babbage and her writings on his analytical engine, is Lady Ada Lovelace (1815-1852).

The only legitimate daughter of the poet Lord Byron, Ada came into contact with De Morgan via her mother, who had been familiar with the Frend family for many years, receiving mathematical lessons from William Frend before her marriage. It was requested that De Morgan give private tuition to Ada, whose mathematical talents far exceeded those of Lady Byron. She began what may be called a correspondence course with De Morgan, the teacher and his pupil communicating by a series of letters, some of which are now housed in the Bodleian Library. These letters, the majority dating from the six-month period between August 1840 and February 1841, contain a mixture of queries and exercises from the pupil, and advice and corrections from the teacher.¹⁰ They reveal Ada's abilities to have reached a high level of sophistication by this point, indicating some years of previous study, although precisely when she began her studies with De Morgan, and for how long, is not certain.¹¹

A wide variety of topics are discussed in the letters, although work on series,¹² the theory of limits,¹³ differential calculus¹⁴ and functional equations¹⁵ is especially prevalent. Ada's reading seems to have been very extensive with De Morgan at one point recommending

⁷ Letter from De Morgan to William Frend, 29 July 1831, quoted in S. E. De Morgan, *op. cit.*, (2), 40.

⁸ He will be discussed in Chapter 5.

⁹ S. E. De Morgan, *op. cit.*, (2), 102.

¹⁰ For a selection of letters from Ada to De Morgan, see Betty A. Toole, *Ada: the enchantress of numbers: a selection from the letters of Lord Byron's daughter and her description of the first computer*, (Mill Valley, California: Strawberry Press, 1992).

¹¹ For a discussion of Ada's mathematical progress under De Morgan's tuition, see Dorothy Stein, *Ada. A Life and a Legacy*, (Cambridge, Mass: MIT Press, 1985), 72-84.

¹² Bodleian Library, Oxford. Dep. Lovelace Byron 170, ff.7-8, 18-19.

¹³ *ibid*, ff.3-4, 18-19.

¹⁴ *ibid*, ff.16, 20, 37, 42-43.

¹⁵ *ibid*, ff.12-15, 20-22, 24-26.

relevant material for the study of acoustics.¹⁶ But he firmly advised her that she should never estimate progress simply by the number of pages read:

You can hardly be a judge of the progress you make, and I should say that it is more likely you progress rapidly upon a point that makes you think for an hour, than upon an hour's quick reading, even when you feel satisfied. That which you say about the comparison of what you do with what you see can be done was equally said by Newton when he compared himself to a boy who had picked up a few pebbles from the shore; and the last words of Laplace were 'Ce que nous connaissons est peu de chose; ce que nous ignorons est immense'. So that you have respectable authority for supposing that you will never get rid of that feeling; and it is no use trying to catch the horizon.¹⁷

This, then, is all that can be ascertained concerning De Morgan's sources of income during his absence from university tuition. But actuarial work and private tuition took up only a fraction of the time that would have been spent on his lecturing duties, with much of his intellectual energy being channelled into work for two very different organisations, both of which gave him the opportunity to work on and write about aspects of the mathematical sciences for two completely distinct sections of the educated community. Some mention has previously been made of one of these organisations, and more will be said presently. The other was not a body with which one would immediately associate De Morgan, being dedicated to an observational science in which, due to his ocular disability, his full participation would have been impossible. Nevertheless, the Royal Astronomical Society was to receive long and enthusiastic support from De Morgan for over thirty years, especially during his absence from London University.

3.1.1 The Royal Astronomical Society

The Astronomical Society of London, as it was originally known, had been founded in 1820, largely on the initiative of two eminent British astronomers, Francis Baily (1774-1844) and William Pearson (1767-1847).¹⁸ Early members included Babbage, Herschel, Airy, and much of the British scientific community, with whom De Morgan was rapidly becoming familiar. He had himself been elected a fellow in May 1828,¹⁹ shortly after his

¹⁶ *ibid*, f.1, De Morgan to Ada Lovelace, [July 1840].

¹⁷ *ibid*, f.14, De Morgan to Ada Lovelace, 15 September 1840.

¹⁸ John L. E. Dreyer and Herbert H. Turner (eds.), *History of the Royal Astronomical Society 1820-1920*, (London: Royal Astronomical Society, 1923), 21-22; Letter from A. De Morgan, Esq., to the President, on the Foundation of the Society, *Monthly Notices of the Royal Astronomical Society*, **26** (1865-66), 1-2.

¹⁹ Possibly on the recommendation of William Frend, who was also an F.R.A.S. Although not a practical astronomer, he had published *Evening Amusements, or the Beauty of the Heavens Displayed* (1804-22),

appointment to London University, and in 1830 became a member of the society's council, on which he was to serve continuously for over three decades. In February 1831, five months before he resigned his professorship, he was elected secretary,²⁰ a position he held until 1839, and again from 1847 to 1855.²¹ This high level of involvement with the society ensured that it occupied a substantial proportion of his time during the period of his resignation. Thus, while not directly allied to his work in mathematical education, his activities in this area do deserve a brief consideration.

De Morgan's work for the Astronomical Society is best understood with reference to the principal British astronomical practitioners of the time since, as a result of his presence on the society's council, many of these men became his colleagues and, in a number of cases, friends. In addition, the work of some of his fellow members would also provide the stimulus and influence for many of his future writings. Consideration of a few of these figures will illustrate firstly, the growing influences on his scientific thinking and public position, and secondly, the widening of his circle of friends in the scientific community, which now, for the first time, extended considerably further than his former Cambridge tutors.

John Herschel (Sir John from 1831) was the son of Sir William Herschel (1738-1822), the renowned German-born astronomer famous for his discovery of the planet Uranus in 1781. Since leaving Cambridge, ten years before De Morgan's arrival, the younger Herschel had established a reputation as one of the leading British exponents of natural philosophy and astronomy, via his numerous observations and publications, most notably his *Preliminary Discourse on the Study of Natural Philosophy* (1830). His relationship with De Morgan began in 1831 via correspondence concerning society business and was at first restricted purely to official matters. Following Herschel's departure for the Cape of Good Hope²² in 1833, the formality was gradually relaxed until, by his return in 1838, the two men were clearly on familiar terms. Their friendship, and correspondence, continued until De Morgan's death in 1871.²³

"an astronomical elementary work of a new character, which had great success; and the earlier numbers went through several editions". - A. De Morgan in *Monthly Notices of the Royal Astronomical Society*, **5**, (1839-43), 144-151, p.150.

²⁰ *Month. Not. R.A.S.*, **2** (1831-33), 24.

²¹ He also held the office of vice-president in 1839-41, 1843-45, 1855-57, 1858-59 and 1860-61.

²² Where he conducted observations on the southern hemisphere.

²³ The Royal Society archives contain no fewer than 383 items of De Morgan-Herschel correspondence.

De Morgan's membership of the society also reinforced the friendship with his former Cambridge tutor, George Airy. In the year of De Morgan's appointment to his professorship, Airy had resigned his Lucasian chair to succeed Robert Woodhouse as Plumian professor of astronomy and director of the Cambridge Observatory. In 1833 he was awarded the Astronomical Society's gold medal for his detection of the 'long inequality' of Venus and the earth,²⁴ having previously received the Copley Medal of the Royal Society for his researches in optics. He was appointed Astronomer Royal in 1835, a post he held until his retirement in 1881, by which time he had become the most influential British astronomer of the century. Like Herschel, Airy became one of De Morgan's most enduring friends as well as a regular correspondent.

The most controversial of all De Morgan's new acquaintances in the society was the Rev. Richard Sheepshanks (1794-1855), a brash Yorkshireman whom he greatly admired for his ability to give any antagonist due credit, later writing: "He was the man from whom I learnt more than from all others of the way to feel and acknowledge the merits of an opponent."²⁵ Born in Leeds and educated at Richmond School, Sheepshanks had studied at Trinity College Cambridge, graduating as tenth wrangler in 1816.²⁶ He was elected to the Astronomical Society in 1825, serving as its secretary immediately before De Morgan, from 1829-31. A very argumentative character, much of Sheepshank's life seems to have been spent in disputes of one kind or another since, as he said, "he was just the person for it; that he had leisure, courage, and contempt for opinions when he knew he was right".²⁷ Coincidentally, what was possibly the most controversial of these disputes began at precisely the time of De Morgan's increased activity within the society.

In 1831, due to the efforts of several prominent members, the society had received a royal charter which, due to a legal formality, had been made out in the name of the then president, Sir James South (1785-1867). Like Herschel, South was an astronomer of private means, who had conducted observations on double stars in the 1820s, being awarded the Royal Society's Copley Medal and the gold medal of the Astronomical Society in 1826.²⁸ As president from 1829 to 1831, he played a major role in petitioning

²⁴ *Month. Not. R.A.S.*, 2 (1831-33), 159-165.

²⁵ S. E. De Morgan, *op. cit.*, (2), 47.

²⁶ John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 5, 486.

²⁷ Augustus De Morgan, Obituary notice of Richard Sheepshanks, *Examiner*, 8 Sept. 1855, 562-3, p.563.

²⁸ *Month. Not. R.A.S.*, 28 (1867-68), 69-72, p.70.

for the award of a charter for the society.²⁹ However, the insistence that, for reasons of expense, his name alone should appear on the charter resulted in his estrangement from other council members. This, together with other disagreements, including the length of tenure of the presidency, led to a fierce debate, which pitted South and Charles Babbage against Richard Sheepshanks and George Airy, an argument which was heightened by a further controversy involving the same players.

South was well known for his exceptionally fine set of instruments, which were housed in his observatory in Kensington. In 1831, he contracted Edward Troughton³⁰ to mount an expensive French 12" telescopic lens, but was dissatisfied with the result and insisted on a new arrangement. When this was denied, he refused to pay and shut Troughton out of the observatory. The result was an action brought by Troughton to recover payment, described by De Morgan as "the most remarkable astronomical trial which ever took place in England".³¹ Sheepshanks agreed to appear as Troughton's scientific advisor, with Babbage acting in the same capacity for South. The case, which grew increasingly acrimonious, drew the attention of the whole British scientific community and caused deep divisions among astronomers throughout the 1830s.³² The action was finally awarded entirely in Troughton's favour in 1838, after five years of legal wrangling. De Morgan, wisely, officially remained neutral, although by virtue of his friendship with Sheepshanks, his sympathies lay well within the Troughton camp.

Of all the prominent astronomers with whom De Morgan came into contact at this time, Francis Baily exercised the greatest influence on the Society in its formative years. As John Herschel later acknowledged, to him "more than to any other, we owe...our early consolidation into a compact, united, and efficient body".³³ Secretary for the first three years of its existence, four times president and eleven times its vice-president, he was a permanent fixture on the Society's council, until his death (while president) in 1844. It has been claimed that "more than to any single individual, the rapid general advance of

²⁹ *ibid*, 71.

³⁰ Edward Troughton (1753-1835) was the leading instrument maker of his generation, and an original member of the Astronomical Society. Despite his experience of mounting telescopes equatorially from 1788 onwards, the problems around South's lens blighted his final years. His vindication in the courtroom came only after his death.

³¹ S. E. De Morgan, *op. cit.*, (2), 61.

³² Michael Hoskin, Astronomers at War: South v. Sheepshanks, *Journal for the History of Astronomy*, **20** (1989), 175-212.

³³ John Herschel, *Memoir of Francis Baily*, in *Journal of a Tour in Unsettled Parts of North America in 1796 & 1797, by the late Francis Baily, F.R.S.*, (London: Baily Brothers, 1856), 1-69, p.57.

practical astronomy in the British islands was due to him",³⁴ with his work on the Cavendish experiment (see below), the reform of the *Nautical Almanac* and, in particular, his superintendence of the [Star] *Catalogue of the British Association* (published posthumously in 1845) providing substantial evidence in support of this assertion.

During the mid-1830s, it was Baily's repetition of the 'Cavendish' experiment to measure the mean density of the earth which occupied much of both his time and, it would seem, De Morgan's attention. The experiment had arisen from an assertion in book three of Newton's *Principia* that the earth was between five and six times as dense as the same volume of water. Several attempts had been made to verify this hypothesis during the eighteenth century, including investigations conducted by Neville Maskelyne and Charles Hutton. However, it was the experiments of Henry Cavendish (1731-1810), using a newly designed apparatus which measured the attraction of two pairs of lead balls to each other, which had provided the most accurate results up to that time. The subject must have intensely fascinated De Morgan during this period, since he wrote many articles in connection with it,³⁵ including an account of how the Cavendish experiment was conducted:

By producing oscillations in leaden balls by means of other leaden balls, and by a process of reasoning wholly free from astronomical data, he inferred that the mean density of the earth was five and a-half times that of water.³⁶ The experiment of Cavendish was published in 1798. It is much to be wished that the experiments of Cavendish should be repeated on a larger scale: but the expense of the apparatus will probably deter individuals from the attempt.³⁷

De Morgan's interest in the matter was apparently shared by his colleagues in the society: an annotated copy of the same article contains the following marginal note:

This was, I believe, the remote cause of the repetition by Mr. Baily. Being a few months afterwards [in 1835] at the Council of the Astronomical Society, something was said about the mean density of the earth, and I just

³⁴ *Dictionary of National Biography*, 2, 427-432, p.431.

³⁵ Technical accounts are given in the following articles written for the *Penny Cyclopædia*: Attraction, 3 (1835), 67-70, Cavendish, Henry, 6 (1836), 392, and Weight of the Earth, 27 (1843), 193-5; together with a longer and more detailed description in: On Cavendish's experiment, *Companion to the Almanac...for 1838*, 26-43.

³⁶ Cavendish's exact value was 5.48.

³⁷ Augustus De Morgan, Maskelyne, in *Gallery of Portraits: with Memoirs*, 6 (London: Charles Knight and Co., 1836), 20-24, p.23.

happened to say "I wish Cavendish's experiment could be repeated". Mr. Airy immediately said, "Ah that would be a good thing." Others agreed, and a committee was appointed on the spot to consider of the practicability, &c. The result was the repetition of the experiment.³⁸

Following a request from the society, the government awarded a grant of £500 to cover the expenses of the new experiment,³⁹ which Baily conducted "in a small upper room twelve feet by twelve, as far removed as possible from the noise and shaking of street traffic",⁴⁰ in his house at 37 Tavistock Place, a short walk from De Morgan's residence on Gower Street. In consequence of his high interest in the project, plus his close proximity to it, Sophia De Morgan tells us that "my husband's visits were frequent to the little room in which the world was weighed".⁴¹ Baily's experiments, using Cavendish's original apparatus substantially modified, eventually improved the accuracy of the original findings, refining the result to 5.6604.

Throughout this period, it was De Morgan's position as secretary which resulted in the bulk of his work on behalf of the society. As professor of mathematics at London University, he had been an energetic and productive worker, and his unanticipated redundancy gave him an extra incentive to direct his intellectual energy elsewhere. Thus, with characteristic enthusiasm, he undertook all duties assigned to him in his new position, plus a few more, even personally overseeing the society's installation at its new premises in Somerset House in September 1834.⁴²

His work at the Society brought him into immediate contact with all its transactions and with all concerned in them, and as he never left London, and was known to be always at hand, much more than the routine duties of an honorary secretary would have fallen to his share, even if he had not voluntarily taken them upon himself. He drew up documents, wrote letters, and arranged for the meetings and the publication of memoirs.⁴³

He also spent much of this period cataloguing the society's library of books and manuscripts, "a task for which his love of books and strong appreciation of the value of

³⁸ Royal Astronomical Society Archives, "Mathematical Biography extracted from the Gallery of Portraits by Augustus De Morgan H.O.M.O. P.A.U.C.A.R.U.M. L.I.T.E.R.A.R.U.M. &c &c &c", handwritten note, f.77.

³⁹ *Month. Not. R.A.S.*, 4 (1836-39), 96.

⁴⁰ S. E. De Morgan, *op. cit.*, (2), 107.

⁴¹ *ibid*, 108.

⁴² The society had previously been accommodated in rather cramped conditions at No.57 Lincoln's Inn Fields. See Dreyer & Turner, *op. cit.*, (18), 63.

⁴³ S. E. De Morgan, *op. cit.*, (2), 43.

accurate bibliography fitted him in an unusual degree".⁴⁴ His work was continued by another Fellow, with a catalogue finally appearing in 1838.

During his absence from university duties, and beyond, the society's *Memoirs* and *Monthly Notices* were also produced under his editorship, work which must have involved some considerable labour. In addition to this he wrote obituary notices for the majority of deceased fellows or, in the event of his personal knowledge proving inadequate, requested those who were better informed to provide him with further information. For example, following the death of Henry Coddington, Whewell was asked to "supply me with any materials or with any remarks on his writings"⁴⁵ in order that De Morgan could compile an adequate account. He also found the time to contribute articles on various historical points connected with astronomy. These papers, while relatively brief, display a high level of historical knowledge and research, providing further evidence, if any were needed, of his immense productivity at this time.⁴⁶

Yet, as hitherto mentioned, his optical handicap meant that De Morgan was not an observational or experimental astronomer, although, as has been shown, he took a keen interest in that side of the subject. On only one occasion, however, did he contribute work to the more specialised *Memoirs* of the Society, his sole paper being a two page mathematical exposition published in 1833.⁴⁷ For this reason, he resisted considerable pressure to become the society's president, writing at the time: "I will vote for and tolerate no President but a practical astronomer.... The President must be a man of brass - a micrometer-monger, a telescope-twiddler, a star-stringer, a planet-poker, and a nebula-nabber."⁴⁸ His skill lay in the ability to describe the practice and complexities of science in such a way as to make them intelligible to the educated layman; thus, while not a

⁴⁴ Dreyer & Turner, *op. cit.*, (18), 64.

⁴⁵ Trinity College Cambridge, Whewell Papers: Add.Ms.a.202¹⁰², De Morgan to William Whewell, 5 Dec. 1845.

⁴⁶ The questions considered in these papers would undoubtedly have been highly novel to the majority of the other fellows, and to the reader today, as can be gleaned from their titles:

a) On the almost total disappearance of the earliest trigonometrical canon, *Month. Not. R.A.S.*, **6** (1845), 221-8.

b) On the opinion of Copernicus with respect to the light of the planets, *ibid*, **7** (1847), 290-3.

c) On the use of the Gregorian calendar for determining the moon's phases with sufficient accuracy to settle the question of moonlight, *ibid*, **11** (1851), 147-8.

⁴⁷ Augustus De Morgan, A new method of reducing the apparent distance of the moon from a star to the true distance, *Memoirs of the Royal Astronomical Society*, **5** (1833), 251-2.

⁴⁸ S. E. De Morgan, *op. cit.*, (2), 153-154.

practitioner himself, De Morgan was still able to serve British astronomy as an effective expounder and populariser.

3.1.2 The Society for the Diffusion of Useful Knowledge

The creation of London University had been just one effect of the intellectual and political upheavals, or what De Morgan referred to as "the social pot-boiling",⁴⁹ of the early nineteenth century. Another result, due to many of the same people, was the formation of the Society for the Diffusion of Useful Knowledge (SDUK). It had long been felt among liberal circles that attempts should be made to facilitate the education of the working man by means of intelligible books on academic subjects published at affordable prices. In 1825, Henry Brougham had published a pamphlet on the question, entitled *Practical Observations upon the Education of the People*, in which he emphasised the need for cheap accessible literature. Various suggestions were mooted during the mid-1820s, including plans by the publisher Charles Knight for a "National Library" which would comprise "a cheap series of books which should condense the information contained in voluminous and expensive works".⁵⁰

Concurrent with these proposals, as well as the movement to found a secular university in the capital, Brougham, together with others, including Lord John Russell, Joseph Hume and James Mill, were also formulating plans for a "Society for promoting General Knowledge".⁵¹ These various schemes were consolidated at a meeting on 6 November 1826, chaired by Brougham, at which several resolutions were passed, chief of which was the following:

That the progress of improvement among the People is chiefly obstructed by the want of Elementary Works upon the various branches of Knowledge, written in a plain manner,...and published at a low price.⁵²

To remove this obstacle, it was agreed to form a body to promote "the composition, publication, and distribution of Elementary Works upon all branches of Useful Knowledge so as to impart useful information to all classes of the community, particularly

⁴⁹ *ibid*, 50.

⁵⁰ Charles Knight, *Passages of a working life during half a century*, vol. 2, (London: Bradbury & Evans, 1864), 37.

⁵¹ Monica C. Grobel, *The Society for the Diffusion of Useful Knowledge, 1826-1846, and its relation to adult education in the first half of the 19th century*, University of London Ph.D. Thesis, (1932), 17.

⁵² *ibid*, 18.

to such as are unable to avail themselves of experienced teachers, or may prefer learning by themselves".⁵³ This was the Society for the Diffusion of Useful Knowledge.

Not surprisingly, considering the nature of its founders, the fundamental characteristics of the society were strikingly similar to the new university, with a strict avoidance of theological issues in its publications and a membership open to all religious denominations. Equally predictably, it also faced much criticism for both political and religious reasons, not least because its title bore a striking resemblance to the conservative Society for the Promotion of Christian Knowledge. With such an analogy "the Society was held by some timorous lookers on to be a sort of conspiracy to subvert all law and religion; and the publication of the *Saturday Magazine*, a markedly religious periodical, just after the appearance of the *Penny Magazine* of the Society, showed the feeling of opposition that was in people's minds".⁵⁴ Yet, despite the inevitable controversy surrounding its inauguration, the response of its target audience ensured that the society was "a remarkable success, and considerably perturbed those people who thought that knowledge should be a monopoly".⁵⁵

The society's first publication was Brougham's *The Objects, Advantages, and Pleasures of Science*, which appeared in March 1827, to be followed by a host of publications on subjects varying from geography and geology to history and philosophy, optics and hydrostatics to botany and medicine. By virtue of their association with London University, several of the professors became involved with the society's activities and contributed to its output of publications. The work of George Long has already been alluded to in 2.2.2, but others, such as Lardner, Lindley and McCulloch, also actively participated, providing treatises on Newton's optics, botany, and *The Principles, Practice, and History of Commerce*, respectively.

However, employment at the university was certainly not a prerequisite for authorship for the SDUK. Indeed, Brougham was keen to enlist as many of country's leading academic writers as possible, one of his most inspired choices being Mary Somerville (1780-1872), whose translation of the *Mécanique Céleste* was published by the society in 1831 as *The Mechanism of the Heavens*. Similarly, the astronomer and mathematician John William

⁵³ *Society for the Diffusion of Useful Knowledge* [Prospectus], (London: William Clowes, [1826]). See also Mary A. De Morgan, *Threescore Years and Ten: Reminiscences of the late Sophia Elizabeth De Morgan*, (London: Richard Bentley and Son, 1895), 206.

⁵⁴ S. E. De Morgan, *op. cit.*, (2), 51.

⁵⁵ Geoffrey T. Garratt, *Lord Brougham*, (London: Macmillan and Co., 1935), 183.

Lubbock (1803-1865) was the co-author, with John Drinkwater Bethune (1762-1844), of an elementary treatise on probability published in 1830, although "a binder's blunder caused this work to be often attributed to De Morgan, despite his frequent disclaimers".⁵⁶

While De Morgan's own involvement with the society pre-dated his association with London University (see 2.1.4), he had yet to have any of his works published by them. Then, in March 1830, he proposed submitting a volume "on the best Method of studying the elements of Mathematics, with elucidations of the difficulties which beginners usually meet with".⁵⁷ Its scheme was approved, "with the proviso that Geometry should receive adequate mention".⁵⁸ Unlike his previous attempt at writing for the SDUK, which had clearly over-estimated the mathematical attainments of its (potential) readership, De Morgan's new book was far more suited to the objectives of the society, being a dissertation on a far less technical theme. On receipt of the work, Lubbock wrote that it was "very elementary and will form I think a very good treatise for the Useful Knowledge".⁵⁹ It was published by the society in 1831 as *On the Study and Difficulties of Mathematics*.

The treatise was a commentary on the various epistemological issues regarding the study of mathematics, being primarily concerned with arithmetic and algebra, although, thanks to the referees' stipulation, geometry was also considered in the closing chapters. It was designed to alleviate the difficulties experienced by those who had studied mathematics as far as elementary algebra and the first few books of Euclid (i.e. equivalent to his lower junior class). Two categories of mathematician were intended to benefit from its use: "teachers of the elements, who have hitherto confined their pupils to the working of rules, without demonstration, and students, who, having acquired some knowledge under this system, find their further progress checked by the insufficiency of their previous methods and attainments."⁶⁰

In writing the *Study*, De Morgan had two principal objectives in mind. The first was to "point out to the student of Mathematics, who has not the advantage of a tutor, the course of study which it is most advisable that he should follow, the extent to which he should pursue one part of the science before he commences another, and to direct him as

⁵⁶ *D.N.B.*, **34**, 227-8, p.227.

⁵⁷ SDUK Archives, University College London, De Morgan to Thomas Coates, 15 March 1830.

⁵⁸ Grobel, *op. cit.*, (51), 190-191.

⁵⁹ SDUK Archives, John William Lubbock to Thomas Coates, 6 May [1830].

⁶⁰ Augustus De Morgan, *On the Study and Difficulties of Mathematics*, (London: SDUK, 1831), iii.

to the sort of applications which he should make".⁶¹ The second was "to treat fully of the various points which involve difficulties and which are apt to be misunderstood by beginners..."⁶² Although the *Study* was to be De Morgan's only book concerning educational matters, it was far from the only work he produced on the subject, being complemented by a series of articles on pedagogic issues written for the society's *Quarterly Journal of Education*, published between 1831 and 1835 under the editorship of George Long.

His thirty-three contributions consist mainly of book reviews and commentaries on mathematical and scientific education, including surveys of tuition offered at Oxford and the École Polytechnique in Paris; they also contain his most significant writings on mathematical education. Unlike the *Study*, which was written for both teachers and students, De Morgan's writings for the *Quarterly* were intended purely for the aid of the former, being recommendations for the improvement of teaching the elementary branches of mathematics. Moreover, whereas the first work was more concerned with algebra, these papers concentrated principally on difficulties connected with arithmetic and geometry. Considered together therefore, they give a good overall impression of the philosophy behind De Morgan's mathematical teaching in the light of his recent university experiences, as well as an insight into his own methods of teaching the rudiments of mathematics to his junior classes.

3.1.3 De Morgan's educational writings

As he had emphasised in his inaugural lecture of 1828, De Morgan believed that one of the chief advantages of mathematical study was its ability to nurture the reasoning capacity of the student:

It is admitted by all that a finished or even a competent reasoner is not the work of nature alone; the experience of everyday makes it evident that education develops faculties which would otherwise never have manifested their existence. It is, therefore, as necessary to *learn to reason* before we can expect to be able to reason, as it is to learn to swim or fence, in order to attain either of those arts. Now, something must be reasoned upon, it matters not much what it is, provided that it can be reasoned upon with certainty.... It is desirable to choose the one which admits of the reasoning being verified, that is, in which we can find out by other means, such as measurement and ocular demonstration of all sorts,

⁶¹ *ibid*, 1.

⁶² *ibid*.

whether the results are true or not.... Now the mathematics are peculiarly well adapted for this purpose.... When the conclusion is attained by reasoning, its truth or falsehood can be ascertained, in geometry by actual measurement, in algebra by common arithmetical calculation.⁶³

Yet, despite his view of arithmetic "as a preparation for algebra, and the higher parts of mathematics",⁶⁴ De Morgan complained that, in their elementary study of the subject, the majority of students were not imbued with any notion of sound reasoning; instead, he said, "all is rule and work".⁶⁵ Moreover, he criticised the lack of rigour in properly defining arithmetical terms and concepts, such as fractions: "He [the pupil] has been accustomed to the consideration of several things of the same kind, but rarely to that of the division of one of these objects into *equal* parts. His *half* has, most probably, been merely a division into any two parts whatsoever, and he can accordingly, with perfect consistency, talk of the larger and the smaller half."⁶⁶ This point was of no small consequence since he had observed from experience that "the want of a familiar acquaintance with common and decimal fractions is the source of nine out of ten of the difficulties which are commonly found in the study of algebra".⁶⁷ The first step, therefore, in training sound mathematicians was to ensure that their notion of all the concepts they were required to employ was rigorous and exact.

Rigour and precision in numerical calculations was of equal importance in early training, but, he said, would not follow until the pupil was confident with the first principles. Even then, however, current classroom methods often presented further obstacles to the learner: "The greatest difficulty which boys find in attaining it [numerical exactness], arises from the custom of writing all the figures on a slate, on which (since beginners in arithmetic rarely write well or evenly) the various columns of figures are mixed, and slant in every possible way. Why should not the young calculator employ the same method as is frequently used by the older one, of writing on paper ruled into small squares, one for each figure. Let this be tried, and we will answer for a much better average rate of correctness."⁶⁸

⁶³ *ibid*, 3.

⁶⁴ Augustus De Morgan, On teaching arithmetic, *Quarterly Journal of Education*, 5 (1833), 1-16, p.14.

⁶⁵ Augustus De Morgan, On mathematical instruction, *ibid*, 1 (1831), 264-79, p.271.

⁶⁶ Augustus De Morgan, On the method of teaching fractional arithmetic, *ibid*, 5 (1833), 209-22, p.210.

⁶⁷ *ibid*, 221-2.

⁶⁸ A. De Morgan, *op. cit.*, (65), 274-5.

He also deplored the lack of regard for cultivating the skill of mental arithmetic in the young, "in fact, we may say, that, in nine cases out of ten, no attention whatever is paid to it.... We should recommend, that up to a later point than that to which we have come, the arithmetic of the child should be all, in a great measure, mental, and also that attention should be paid to instructing him in the most simple method which the case will allow of."⁶⁹ For De Morgan, skill in arithmetical calculation was the bedrock of all further progress in mathematics. Thus, his fundamental plea to school instructors, with regard to the arithmetical instruction they gave to their pupils, whether they were intended to study mathematics or not, was simple: "make them arithmeticians, rational ones if you can; but, at any rate, make them master the processes of computation".⁷⁰

For those who progressed to the study of algebra, the principal difficulty highlighted was the inability of most young students to grasp the nature of abstract proofs. Indeed, De Morgan strongly asserted that, to the majority of beginners in mathematics, general demonstrations instilled no confidence whatsoever.

We have before observed, that it is necessary to learn to reason; and in no case is the assertion more completely verified than in the study of algebra. It was probably the experience of the inutility of general demonstrations to the very young student that caused the abandonment of reasoning which prevailed so much in English works on elementary mathematics. Rules which the student could follow in practice supplied the place of arguments which he could not, and no pains appear to have been taken to adopt a middle course, by suiting the nature of proof to the student's capacity.⁷¹

In order to enable the student to overcome his difficulties when studying algebra, the advice offered by De Morgan is probably identical to that which he gave to the pupils in his lecture room and in private: never study the subject purely by reading. The reason given was that reading alone cannot provide the conviction that comes from proving something on paper, especially since algebraic texts were filled with processes, demonstrations and results which were not always justified or displayed in their entirety.

These must not be taken on trust by the student, but must be worked by his own pen, which must never be out of his hand while engaged in any algebraic process. The method which we recommend is, to write the whole of the symbolical part of each investigation, filling up the parts to

⁶⁹ A. De Morgan, *op. cit.*, (64), 5-6.

⁷⁰ *ibid*, 13-14.

⁷¹ A. De Morgan, *op. cit.*, (60), 62.

which we have alluded, adding only so much verbal elucidation as is absolutely necessary to explain the connexion of the different steps, which will generally be much less than what is given in the book.... If, while proceeding in this manner, any difficulty should occur, it should be written at full length, and it will often happen that the misconception which occasioned the embarrassment will not stand the trial to which it is thus brought.⁷²

A major problem encountered by the student of both arithmetic and algebra was the validity of negative numbers in mathematical operations. In matters concerning their treatment, De Morgan was again influenced by William Frend, who is an example of a peculiarly English phenomenon in mathematics at this time - a mathematician who totally rejected all use of negative quantities.⁷³ However, even in the English mathematical community, Frend was very much in the minority in the views he held, with his future son-in-law adopting a more moderate position. Like many contemporaries, De Morgan naïvely treated negative quantities as expressions which had no epistemological validity unless couched in the correct form. For example, the assertion that $3 - 9 = -6$ would, in De Morgan's view of arithmetic, be meaningless. However, if it were arranged as $3 + 6 = 9$, say, or $9 - 6 = 3$, then these expressions would be well-defined. Similarly, in algebra, he maintained that the expression $a - b = c$ would only be meaningful if $a \geq b$.

In geometry (a word which, in these articles, was always used synonymously with Euclid), De Morgan was equally insistent that the student's progress would be retarded unless he was comfortable with the preliminary notions and definitions he was given. For this reason, he rejected the vague Euclidean definitions of words such as point, straight line and angle, recommending the use of repeated drawn examples to leave the student in no doubt as to what he was considering. For example, "instead of defining parallel lines, as those which would never meet, though ever so far produced, a definition which it is impossible to verify, let parallel lines be drawn, and let the student be required to verify, by measurement, the property that any third line makes equal angles with the two parallels".⁷⁴

⁷² *ibid*, 60.

⁷³ This unusual position had been illustrated in his *Principles of Algebra* (London: J. Davis, 1796) in which he had also expressed misgivings about fractions.

⁷⁴ Augustus De Morgan, On the method of teaching the elements of geometry, part 1, *Q.J.E.*, 6 (1833), 35-49, p.41.

As with arithmetic and algebra, while a thorough comprehension of first principles was deemed essential to further progress, De Morgan maintained that excessive preference had hitherto been given to the acquisition of facts over the cultivation of reasoning ability. He claimed that "ninety-nine parents out of a hundred are more likely to ask their sons, How many books of Euclid have you read? How far have you got on in algebra? than, In what manner have you studied? Do you understand what you have read?"⁷⁵ While acknowledging that some factual knowledge was necessary in order to provide a sound basis for reasoning, he argued that, with the current prevalence of memory and rote-learning in schools, the information thereby obtained provided no such foundation: "Many a youth who can *say* the first book of Euclid cannot say whether it would or would not do equally well to reverse the order of all the propositions."⁷⁶

Regarding the propositions themselves, De Morgan was again conscious of the need to simplify demonstrations for the beginner, recommending that the majority of theorems from the first four books should initially be proved to students by simple measurement or ocular demonstration. He also listed a further twenty-eight which, in his opinion, could be omitted from a course of geometrical instruction altogether, due to their relative insignificance. He then categorised the remaining propositions into three types. The first he classed as problems, that is, propositions which merely involved constructions, as in Euclid I.46.⁷⁷ The second type consisted of "theorems in which some equality is asserted, which may be verified by cutting out some parts of the figure and laying them over others".⁷⁸ Finally, the third category contained those theorems "in which areas are asserted to be equal to other areas, differing in form from themselves, though not in magnitude, such as Book I.47".⁷⁹

It was at this point, De Morgan recommended, that an introduction to the concepts of logic would facilitate students' understanding of geometrical arguments.⁸⁰ As he said:

⁷⁵ A. De Morgan, *op. cit.*, (65), 266.

⁷⁶ *ibid*, 269.

⁷⁷ "To describe a square upon a given straight line."

⁷⁸ A. De Morgan, *op. cit.*, (74), 46.

⁷⁹ *ibid*, 47.

⁸⁰ His writings on geometrical education, both in the *Study* and the articles for the *Quarterly Journal*, provide the first published evidence of De Morgan's interest in logic, although at this point, it was utilised purely as a pedagogic tool. He later elaborated his ideas in a short book for his students entitled *First Notions of Logic (preparatory to the study of geometry)*, published in 1839. This was later incorporated as the first chapter of his *Formal Logic* in 1847, by which time his interest in logic had transcended its utility merely as an aid to geometry, and was manifesting itself in the publication of research papers concentrating more on the intrinsic nature of the subject itself.

The principles on which geometrical propositions are established belong to the totally distinct and equally simple science of logic; and since geometry without logic would be absurd, it is desirable that the principles of the latter science should be studied with precision previously to employing them upon the former.⁸¹

One of the principal sources of confusion when initiating students into the study of geometrical demonstrations was the distinction between a proposition and its converse. So, for example, the statement that 'all equilateral triangles are equiangular' was often taken as proof that 'all equiangular triangles are equilateral'. "These errors," said De Morgan, "should be guarded against beforehand, by exercising the pupil in simple deductions, such as are to be found in every syllogism, taking care that all the terms used have reference to objects with which they are familiar. It should be illustrated to them that the truth of an argument depends on two distinct considerations, the truth of the premises, and the manner in which the conclusion is deduced from them."⁸²

He also drew attention to the problems encountered when employing the method of *reductio ad absurdum* in geometrical arguments, attributing the chief cause of these difficulties to an ignorance of the difference between *contradictory* and *contrary* propositions. For example, the statements 'all As are Bs' and 'one A is not a B' are contradictory, whereas the contrary of the first is 'all As are not Bs'. In other words, with two contradictory propositions, both cannot be true, but one must be; with two contrary propositions, while they cannot both be true, they may both also be false. This distinction, crucial to the students' understanding of Euclidean proofs by the method of contradiction, was, in De Morgan's opinion, rendered far more intelligible by the combined study "of the forms of logic with the reasoning of geometry".⁸³

Finally, when the student was familiar with the terminology, concepts and results of the first four books, as well as with the rudiments of logical processes, *and only then*, he was ready to be taught how to prove geometrical theorems rigorously. Once again, De Morgan did not regard the Euclidean order as sacrosanct, even suggesting that "it would not be contrary to good logic, to assume the whole of the first book of Euclid, and from it to prove the second, provided that afterwards the first book were proved,...[since] the

⁸¹ Augustus De Morgan, On the method of teaching geometry, part 2, *Q.J.E.*, 6 (1833), 237-51, pp.238-9.

⁸² A. De Morgan, *op. cit.*, (65), 272-3.

⁸³ A. De Morgan, *op. cit.*, (81), 251.

order in which the premises come, does not affect the soundness of the conclusion..."⁸⁴ Yet irrespective of arrangement, it was essential, when presenting proofs to the student, that care should be taken to ensure that every step was perfectly logical, so as to create no doubt in the mind of the student as to the validity of the final result. An illustration of this was provided in chapter 14 of the *Study*, where De Morgan presented a proof of Pythagoras's Theorem broken up into syllogistic form.⁸⁵

All of De Morgan's comments on geometry have hitherto concerned the first four books of Euclid, as well as book six. But he also had much to say on the Euclidean theory of proportion, contained in the problematic fifth book. While acknowledging that its standard of rigour was widely regarded as superior to that of the preceding books, he also pointed out that, owing to its highly convoluted presentation, it "is pretty generally admitted to be very difficult, if not absolutely unintelligible to the young..."⁸⁶ Indeed, he claimed "it has been customary for mathematical students among us to read the Fifth Book of Euclid; frequently without understanding it".⁸⁷ For this reason he proposed substituting a more obvious method which used the common arithmetical notions of proportion instead of the traditional geometrical ones.

Admitting that this would not be as precise as strict adherence to the standard Euclidean mode, he insisted that "a less rigorous but intelligible process, is better than a perfect method, which cannot be understood by the great majority of learners".⁸⁸ Moreover, he said, an increased understanding of the theory of proportion would facilitate the student's progress through book six. He developed his ideas further in a short book entitled *The Connexion of Number and Magnitude, or an attempt to explain the fifth book of Euclid*, published in 1836, recommending teachers either to use it to accompany their teaching of the fifth book, or to abandon the Euclidean treatment altogether in favour of the numerical approach: "We would say to all, teach the fifth book, *if you can*; but we would have all remember that there is an *if*."⁸⁹

⁸⁴ A. De Morgan, *op. cit.*, (65), 275.

⁸⁵ A. De Morgan, *op. cit.*, (60), 73-75.

⁸⁶ A. De Morgan, *op. cit.*, (65), 269.

⁸⁷ Augustus De Morgan, *The Connexion of Number and Magnitude*, (London: Taylor and Walton, 1836), iii.

⁸⁸ A. De Morgan, *op. cit.*, (65), 277.

⁸⁹ A. De Morgan, *op. cit.*, (81), 250.

In all De Morgan's writings on the subject of elementary mathematical education, one particular tenet of his overall philosophy comes across very clearly: the expediency of removing unnecessary difficulties for the beginner. While his ultimate goal was to produce sound mathematical reasoners, he was fully aware of the fundamental need to make the subject intelligible to the novice; and, if this pursuit of intelligibility involved a temporary sacrifice of rigour early in the student's studies, that was a small price to pay for the clarity with which he would receive the notions on which his reasoning skills would thereafter be grounded. This emphasis on facilitation is reflected in the numerous methods De Morgan suggested for surmounting common conceptual problems experienced by the elementary student, from the use of beads on an abacus to assist in arithmetical visualisation, to marked rods for improved perception of fractions.

His omission of the confusing notions of ratio and proportion advanced in book five has already been mentioned, but De Morgan was also highly critical of the eleventh book (on solid geometry), recommending its rejection in favour of the more recent work by the Frenchman Adrien-Marie Legendre (1752-1833).⁹⁰ A further aid to solid geometric cognisance was his rejection of perspective drawings in favour of the use of models when teaching the subject. While this approach was certainly innovative, it clearly puzzled De Morgan why its use was not more widespread: "We should like to know to how many mathematical teachers *per cent* it has occurred, instead of drawing one plane inclined to another on a paper, to fold the paper itself, and place the two folds at the required angle? Would it give too much trouble? Does the pupil *say* his proposition as well without it?"⁹¹

While it is evident that De Morgan had clearly-defined and emphatically-stated ideas on how mathematics should be inculcated, it should not be taken for granted that the points he made and the remedies he suggested were unique, or even original, to him. After all, taken together, his educational writings were composed by a man still in his twenties with the benefit of only three years of teaching experience behind him. Yet he clearly had much to say on the subject of mathematical instruction. Where, then, did he cull his didactic ideas from? Our ability to fully answer this question is hindered by what we may call De Morgan's tendency towards selective citation. In all his works of this period, references are sparse and, if a name is mentioned, the corresponding work does not always accompany it. However, in the *Study* he does implicitly indicate at least some of his

⁹⁰ Translated into English in 1824 by Sir David Brewster.

⁹¹ A. De Morgan, *op. cit.*, (81), 250.

sources by recommending the study of three fairly recent works by French mathematical authors.⁹²

These were Étienne de Condillac's *La langue des calculs* (1798), articles on algebra in the French *Encyclopédie* by Jean D'Alembert (1717-1783), and a lengthy work dedicated to the instruction of arithmetic, algebra and geometry, entitled *Essais sur l'enseignement des mathématiques* (1805),⁹³ by Sylvestre Lacroix (1765-1843). He also appears to have drawn on lectures delivered by Pierre-Simon Laplace (1749-1827) at the École Normale in 1795, although no specific reference is given. However, it was Lacroix's *Essais* which seems to have served as the principal source for his pedagogic views, bearing striking resemblances in its theories and recommendations to those we have presented above. Furthermore, the majority of Lacroix's suggestions are followed in De Morgan's educational writings, in many cases word for word.⁹⁴

For example, the works of both Lacroix and De Morgan repeatedly stress similar beliefs, such as an unbridled opposition to memory and rote-learning, and the need for simplicity in elementary tuition. Both also place much emphasis on the use of history and chronology in teaching mathematics, in other words, introducing students to notational forms and concepts in their 'natural' order. Take, for instance, the following extract from De Morgan:

The new symbols of algebra should not be all explained to the student at once. He should be led from the full to the abridged notation, in the same manner as those were, who first adopted the latter. For example, at this period he should use *aa*, *aaa*, &c., and not a^2 a^3 , and should continue to do this until there is no fear of that confusion of $2a$ and a^2 , $3a$ and a^3 , &c., which perpetually occurs.⁹⁵

But it would appear that Lacroix's most important effect on De Morgan was to direct his attention towards the joint study of geometric and syllogistic reasoning. In this, Lacroix showed the influence of Euler, who had advocated the use of logic to facilitate geometrical study in his *Lettres à une Princesse d'Allemagne sur quelques sujets de physique et de philosophie* (1768-72), although this work only exercised an indirect

⁹² A. De Morgan, *op. cit.*, (60), 63.

⁹³ A third edition had recently (1828) appeared.

⁹⁴ In drawing these comparisons between the works of Lacroix and De Morgan, I am particularly indebted to Maria Panteki, from whose forthcoming paper, *The mathematical background of Augustus De Morgan's logic of relations, 1830-1860*, I was able to derive much of my information.

⁹⁵ A. De Morgan, *op. cit.*, (65), 277.

influence on De Morgan since, as he later said, the *Study* was written "before I knew what Euler had done".⁹⁶ However, whereas the continental authors were following the model of *La logique, ou l'art de penser* (1662),⁹⁷ De Morgan turned to the Aristotelian syllogistic methods contained in the more recent *Elements of Logic* by Richard Whately (1787-1863), a work with which he had probably been familiar since its publication in 1826.⁹⁸ In any case, it is one of the few works that he actually cites.⁹⁹

This reluctance to adequately cite his sources in these educational writings may, at first sight, appear to suggest an attempt on the part of De Morgan to present these pedagogic opinions as purely his own. But, on reflection, any imputation of plagiarism seems not only unjustifiable, but irrelevant. We have to remember that he was writing for a society which had been formed for the dissemination of information, rather than the promotion of original work, an intention encapsulated in Lord John Russell's emphatic declaration: "the Society to which I belong is one for the distribution and not for the discovery of knowledge".¹⁰⁰ In other words, the whole *raison d'être* of the SDUK was to "put the discoveries made by others, in different departments of knowledge, in a form, (both as regards text and price), which they considered best for the uninstructed reader."¹⁰¹

Furthermore, the audience for whom De Morgan would have written these works would have largely consisted of educated working men, to whom the mention of names such as D'Alembert, Laplace and Lacroix would have meant very little, if anything at all. Hence his acknowledgement in the *Study* that "I have followed the method adopted by several of the most esteemed continental writers"¹⁰² would presumably have been deemed sufficient information for most of his readers. Indeed, since the vast majority of the society's readership would have had extremely limited access to foreign language tuition, it would probably have seemed almost futile to cite publications which were only available in

⁹⁶ Augustus De Morgan, *Formal Logic*, (London: Taylor and Walton, 1847), 323.

⁹⁷ A book written by A. Arnauld and P. Nicole in reaction to the medieval Aristotelian scholasticism, corresponding to the Cartesian view of science.

⁹⁸ He later wrote: "My last schoolmaster [Parsons], a former Fellow of Oriel, was a very intimate college friend of Richard Whately, a younger man. Struck by his friend's talents, he used to talk of him perpetually, and predict his future eminence. Before I was sixteen, and before Whately had even given his Bampton Lectures, I was very familiar with his name, and some of his sayings." - A. De Morgan, *A Budget of Paradoxes*, (London: Longmans, Green, and Co., 1872), 196.

⁹⁹ A. De Morgan, *op. cit.*, (81), 241, 244.

¹⁰⁰ Letter from Lord John Russell to Capt. W. Forman, 14 Aug. 1832, quoted in Grobel, *op. cit.*, (51), 20.

¹⁰¹ *ibid.*

¹⁰² A. De Morgan, *op. cit.*, (60), iii.

French. Thus, far from being a plagiarism of the ideas of Lacroix and others, De Morgan's educational writings can be seen as a forum whereby these progressive continental views were aired in English for the first time.

3.1.4 De Morgan's other work for the SDUK

The *Quarterly Journal of Education* was not the only periodical published by the SDUK to which De Morgan was a regular contributor. The *Companion* to the society's *Almanac* was an annual publication to which he contributed twenty-seven articles in consecutive years from 1831. Being free to supply articles of general interest, his contributions varied from year to year according to his current interests, fluctuating from matters concerning insurance, to astronomy, calendar reckoning and decimal coinage. His interest in the history of science formed the inspiration for a third of these contributions, as well as providing the impetus for his participation in another of the society's publications. Between 1833 and 1836, he wrote twelve potted biographies for the *Gallery of Portraits: with memoirs*, his assigned luminaries including Halley, Laplace, Descartes and Leibniz.

A more substantial venture was also inaugurated in 1833. Encouraged by the success of its *Penny Magazine*, the society decided to publish a full-scale encyclopædia in penny numbers and monthly parts. This became the society's *Penny Cyclopædia*, whose chief novelty, compared with many of the existing compendia, was that "every article was to be original; to be furnished by various men, each the best that could be found in special departments of knowledge".¹⁰³ Thousands of articles were commissioned, with contributors including Charles Bell, Brougham, Key, Lubbock, Lindley, Horner, Rosen, Sheepshanks and George Long, who also served as editor.¹⁰⁴ As with his work in that capacity for the *Quarterly Journal*, Long's editorship of the *Cyclopædia* was exemplary in its efficiency; it was reputed that the publication "was never twelve hours behind its time in all the monthly appearances of as many years".¹⁰⁵ Whether this was true or not, it quickly became a highly-regarded work of reference.

De Morgan provided the majority of the mathematical articles for the *Cyclopædia*, but his contributions also extended into other scientific areas, especially astronomy and history of

¹⁰³ Knight, *op. cit.*, (50), 201.

¹⁰⁴ Grobel, *op. cit.*, (51), 471-2.

¹⁰⁵ *Address of the Committee of the Society for the Diffusion of Useful Knowledge*, (London: Charles Knight and Co., 1846), 11.

Table 1

De Morgan's Publications for the S.D.U.K.

TITLE	DATE OF PUBLICATION
<i>On the Study and Difficulties of Mathematics</i>	1831
<i>Elementary Illustrations of the Differential and Integral Calculus</i>	1832
<i>The Elements of Spherical Trigonometry</i>	1834
<i>Examples of the Processes of Arithmetic and Algebra</i>	1835
<i>An Explanation of the Gnomonic projection of the sphere</i>	1836
<i>The Differential and Integral Calculus</i>	1842
<i>The Globes Celestial and Terrestrial</i>	1845

science. By the time the undertaking was completed in 1846,¹⁰⁶ his contributions numbered well over 700 individual articles, amounting to an estimated sixth of the total volume.¹⁰⁷ Many of these are extremely lengthy, with more than a few being concerned with somewhat technical subjects, but all are characterised by an innate readability derived no doubt from his desire to render each subject intelligible to the general reader. Interestingly, it is one of the shorter pieces which is probably his most significant: in an article entitled "Induction (Mathematics)",¹⁰⁸ De Morgan introduced the phrase, though not the method, of *mathematical induction*, to describe a process widely used, but unnamed, by mathematicians for generations.

In tandem with these works, De Morgan also produced a series of other titles for the society, in his own right, being mainly text-books on various mathematical topics. With the increase in the number of his publications during this period, much of his time must have been spent proof-reading, as is revealed by the following amusing letter written during the preparation of his book on spherical trigonometry sometime in 1833: "A tutor at Cambridge now living, was one day trying to make a pupil understand the difference between a^7 which means 7 *as multiplied* together and $7a$ which means 7 *as added* together. The young man, after some consideration said, 'I think Sir, I understand the

¹⁰⁶ Twenty-seven volumes were published between 1833 and 1843, with a two-volume supplement following in 1845-46. A second supplement appeared in 1858.

¹⁰⁷ A full list of these articles is given in S. E. De Morgan, *op. cit.*, (2), 407-14.

¹⁰⁸ *Penny Cyclopædia*, 12 (London: Charles Knight and Co., 1838), 465-66.

difference; but *don't you think it a needless refinement!*' On looking at the corrections you will see that I have altered your printers $\cos 2\delta$ into $\cos^2\delta$. I assure you this is not a needless refinement..."¹⁰⁹

The society finally suspended its activities in 1846, having decided that the deficiency it had been created to counter no longer existed. By this time, De Morgan had established himself as one of the country's foremost mathematical authors in both popular and technical works. These had not only furthered his own career but also the welfare of the society, which, in its closing statement, duly recognised his work on its behalf:

In various works of the mathematical sciences, the Society has had the satisfaction of doing for non-academical readers throughout the empire what the University of Cambridge has done within the last thirty years for its own students, namely, of placing before them, in our own language, the methods of the mathematicians of foreign countries. In this department the Society acknowledges its obligations to Professor De Morgan, both for the works which he has contributed to the series, and for his general advice and assistance.¹¹⁰

But, as can be inferred from the title attached to his name, by this point De Morgan was no longer solely reliant on the income derived from his books, actuarial work or private pupils, having long since returned to his former place of employment. This development may at first seem surprising, considering the vehemence with which his resignation had been tendered in 1831. But following the changes inaugurated at London University during the intervening period, the institution to which he was to return was a very different one to that which he had left five years earlier. The details surrounding his restoration will be discussed in 3.3, but first we must consider the state of mathematics at the university during De Morgan's absence.

3.2 Mathematics and the university

3.2.1 De Morgan's Replacement

The situation in which the London University found itself in the summer of 1831 was far from enviable. The bitter disputes and recriminations of the preceding three years had resulted in the resignations, not just of De Morgan and his colleagues in the chairs of

¹⁰⁹ SDUK Archives, De Morgan to Thomas Coates, [July 1833].

¹¹⁰ *op. cit.*, (105), 16-17.

Greek and oriental languages, but of many of the initial professoriate, leaving a severely depleted staff. Perhaps more importantly, in the short-term at least, the public controversies, and the Pattison affair in particular, had dramatically eroded both its public credibility and the number of students enrolled for its lectures. Consequently, the venture which a matter of months before had seemed so secure was now in an extremely precarious financial situation with its long-term prospects appearing exceedingly uncertain.

Notwithstanding the institution's great potential for healthy class sizes, an attribute which had played a major role in the high number of candidates for chairs in 1827-8, its present circumstances would hardly have seemed encouraging to potential applicants for the professorships now vacant. Indeed, it was almost inevitable that there would be less interest in the chairs than there had been four years earlier, since the recent adverse publicity would certainly discourage many people from applying. As Olinthus Gregory wrote: "Had it not been for the impression made upon the public by Pattison's business, I had a person in my eye who would have suited admirably. He now declines offering himself."¹¹¹ Nevertheless, if the university was to continue, the chairs needed filling, an urgency heightened by there being only two or three months before the commencement of the new session in the autumn. Consequently, advertisements for the professorships of Greek and mathematics were ordered to appear as soon as possible.¹¹²

The first application for the chair of mathematics was received on 13 August,¹¹³ three weeks after De Morgan's resignation. Another followed two days later.¹¹⁴ This initial interest must have been very gratifying to the council, since both applications arrived before the vacancy had been advertised. However, following the appearance of the advertisement, no substantial increase in applications was forthcoming, with only three further letters materialising by the end of August. Given that the deadline for submissions for the professorships of mathematics and Greek had been set at 15 September, it was hurriedly ordered that "the Advertisement that these Chairs are vacant be repeated".¹¹⁵ This produced three further applicants for mathematics, but, whereas a new professor of

¹¹¹ UCL College Correspondence, hereafter cited as 'UCC', No. 2205, Olinthus Gregory to Thomas Coates, 19 Sept. 1831.

¹¹² Committee of Management Minutes, vol. I, f.2.

¹¹³ Council Minutes, vol. II, f.322.

¹¹⁴ *op. cit.*, (112), f.2.

¹¹⁵ *ibid*, f.10.

Table 2
Candidates for the Mathematical Chair - 1831.

CANDIDATE	AGE	DATE OF APPLICATION	DATE OF RECEIPT IN MINUTES	PREVIOUS EDUCATION
William Sankey	?	-----	13 Aug 1831	Trin. Coll. Dublin
John Radford Young	32	15 Aug 1831	15 Aug 1831	Private
Wilton George Turner	20	16 Aug 1831	22 Aug 1831	London Univ.
Michael T. S. Raimbach	23	18 Aug 1831	22 Aug 1831	Sydney Coll. Cam
John Walker	63	23 Aug 1831	29 Aug 1831	Trin. Coll. Dublin
John Buck	39	5 Sept 1831	13 Sept 1831	Queens' Coll. Cam
William Shortt Thynne	21-23	9 Sept 1831	13 Sept 1831	Trin. Coll. Dublin
Eneas McIntyre	40	11 Sept 1831	13 Sept 1831	King's, Aberdeen
George Laing	?	13 Sept 1831	21 Sept 1831	Private
Mr. Dowling	?	-----	21 Sept 1831	-----
Guinibert Debac	38	21 Sept 1831	1 Oct 1831	École Poly. Paris
George James Pelly White	24	4 Oct 1831	8 Oct 1831	Trin. Coll. Camb.

Greek had been appointed by 21 September, the mathematical chair was not filled until a month later, a mere two weeks before the start of the new session.

The competition for the mathematical chair in 1831 shares two distinguishing features with that of 1827-8. The first was a prolonged duration due to an extension of the closing date. As with the previous contest, applications were not so slow in arriving but, again, it took some time for the successful candidate to emerge. The explanation for the delay was the same in both cases: as shall be seen, the standard of applicants was initially disappointing and the council very obviously demurred for as long as possible until a more suitable candidate presented himself. The second characteristic concerns the applicants themselves: they were again, with one possible exception, complete mathematical non-entities, never achieving eminence, or even minor repute, in the field. Even the successful candidate was to achieve no lasting distinction.

In fact, in general, the competition of 1831 appears as a hurried, condensed and more lack-lustre version of its predecessor, although given the circumstances surrounding it, this is hardly surprising. Possibly for these rather dubious qualities, plus the scarcity of relevant information, this competition, its winner and his subsequent work as professor of

mathematics have received no attention whatsoever in previous histories of University College. Yet this omission does not negate their significance as an intrinsic element in the story of mathematical tuition at London University, and, as a forgotten and ignored part of the study of De Morgan and university mathematics in London during this period, due consideration is essential to this thesis.

Even the briefest of comparisons with Table 1 in Chapter 2 will serve to illustrate the comparative lack of interest in the chair of mathematics in 1831. At twelve, the number of applicants was just over a third of its earlier counterpart with only three of the candidates from the previous competition bothering to enter, although it is interesting to note that two of their applications were the first to arrive. A notable coincidence is that, of the candidates whose ages we can ascertain, the average is just over 33, almost exactly the same as that for the first contest. Applicants also came from a similar variety of geographical and educational backgrounds, with three Scots, two Irishmen and one Frenchman competing. Once again, there is some discrepancy between those applicants whose letters survive and those whose applications are recorded in the minutes, with one applicant being almost completely unnoted, apart from a brief mention in the minutes where his candidature is registered and an instruction given to "enquire into Mr Dowling's qualifications".¹¹⁶

The first candidate to apply was William Sankey, although his letter no longer survives. Four years earlier, he had applied for the elementary post at the new university, being rejected when the decision was made to combine that position with the higher chair. His current application was the first of three from alumni of Trinity College, Dublin, although Sankey himself was Scottish. Although his age is unknown, he received his B.A. in 1810, followed by a Master's degree four years later.¹¹⁷ This would make him at least forty by 1831. His only mathematical publication to date was a collection of papers published in 1825 with the rather old-fashioned title of *The Geometrical Rectification of any arc of the Circle, founded on the principles of ultimate and limiting ratios; to which is added, an examination of some curious properties of a quadratrix*. According to his application of 1827, he was equally distinguished as a classicist, since in Dublin "there was no separate Premium allotted for the Sciences & Classics but both were included in the same

¹¹⁶ *ibid*, f.17.

¹¹⁷ *A Catalogue of Graduates who have proceeded to degrees in the University of Dublin, 1591-1868*, (Dublin: Hodges, Smith, and Foster, 1869), 504.

Examination".¹¹⁸ However, since his classical writings were no more impressive or profound than those on mathematics, Sankey's application was again unsuccessful.

Sankey's rejection was probably also caused by the fact that he had published nothing new in the intervening four years. The same could not be said of the second applicant, also ultimately unsuccessful in both competitions, John Radford Young. Since his first rejection, Young had continued to teach privately in London, where he produced three more mathematical works, including textbooks on the *Elements of Analytical Geometry* (1830) and the *Elements of the Differential Calculus* (1831). Although his 1827 application was never officially registered as having been received, the same was not the case in 1831 - his letter receiving acknowledgement on the day it was written.¹¹⁹ Yet, despite this, his growing reputation as a competent textbook author, and being "known to Dr Gregory, and to Dr Birkbeck, who can both...speak as to my qualifications",¹²⁰ he was rejected again. Even the fact that Robert Fawcus - a student who at the end of the 1830-31 session won the first prize in De Morgan's higher junior class¹²¹ - had been his pupil for two years failed to impress the selectors.

The third candidate to apply was one of the most interesting, being very probably the first former student of the university to apply for an academic post in it. He was also the only applicant to receive a personal endorsement from the erstwhile professor of mathematics. Wilton George Turner was the younger brother of the chemistry professor, Edward Turner, whose testimonial on his behalf informs us that he was a very promising young mathematician, initially educated at the Edinburgh Academy. On entering London University, he had attended the lectures of De Morgan, Lardner and his brother, especially distinguishing himself in mathematics where he won the first certificate in De Morgan's higher senior class.¹²² The elder Turner, convinced that "should he continue to pursue these studies, he will become eminent as a Mathematician",¹²³ was supported by De Morgan who also provided a testimonial, which unfortunately has not been preserved.

¹¹⁸ UCC (Applications), William Sankey to Leonard Horner, 22 May 1827.

¹¹⁹ *op. cit.*, (112), f.2.

¹²⁰ UCC, No. 2173, John Radford Young to Council, 15 Aug. 1831.

¹²¹ *University of London. Distribution of the Prizes and Certificates of Honours....Session 1830-1831*, (London: George Woodfall, 1831), 25.

¹²² *University of London. Distribution of the Prizes and of the Certificates of Honours....Session 1829-1830*, (London: John Taylor, 1830), 32.

¹²³ UCC, No. 2174, Edward Turner to Council, 17 Aug. 1831.

However, at only twenty, Wilton Turner was the youngest applicant, which together with his lack of teaching experience would, it was acknowledged, "tend to diminish his influence with Students, and increase the difficulty of preserving order".¹²⁴ But, on the other hand, he anticipated that "the circumstance of my being educated at the University will be some recommendation - partly from my being well known to the students - & partly from being intimately acquainted with the mode of instruction hitherto adopted in the class of Mathematics".¹²⁵ This hope was, however, to prove unfounded: the council obviously did not rate their university's mathematical tuition as highly as that of Cambridge and, despite the obvious comparisons which could be drawn with De Morgan's selection three years previously, Turner was no wrangler. Following his rejection for this chair, plus another for a proposed professorship of mineralogy in 1834,¹²⁶ he lowered his sights, teaching mathematics at the London University School (see below) from 1832 to 1839.¹²⁷

The first Cambridge man to enter the competition was Michael Thomson Scott Raimbach, eldest son of the sculptor Abraham Raimbach (1776-1843),¹²⁸ whose biography he edited for publication in 1843.¹²⁹ He had been educated in Westminster School and Sydney College Cambridge, from where he graduated as 21st wrangler in 1830. However, from material available, this mediocre wranglership seems to have been Raimbach's only qualification for the post, having no mathematical publications to his name, and no specified teaching experience. His realisation of the inferiority of his credentials is shown by a letter from him, written in mid-October, when "hearing that Mr. White of Trinity is a candidate for the Mathematical Chair at the London University, I beg to withdraw myself from any further competition".¹³⁰ He too later became a teacher at the University School,¹³¹ before serving for nearly thirty years as a Royal Naval instructor.¹³²

¹²⁴ *ibid.*

¹²⁵ *ibid.*, No. 2203, Wilton George Turner to Council, 16 August 1831.

¹²⁶ *ibid.*, No. 4148, Wilton George Turner to Council, 11 Jan. 1834; No. 3260, Report of the Committee appointed to examine the testimonials of the Candidates for the Chair of Mineralogy, [24 Jan. 1834].

¹²⁷ Temple Orme, *University College School, London. Alphabetical and Chronological Register for 1831-1891*, (London: H. Walton Lawrence, 1892), 17.

¹²⁸ *D.N.B.*, **47**, 171-2.

¹²⁹ Michael T. S. Raimbach, (ed.), *Memoirs and Recollections of Abraham Raimbach*, (London: F. Schobeel, 1843).

¹³⁰ UCC, No. 2241, Michael Raimbach to Thomas Coates, [18 Oct. 1831].

¹³¹ Orme, *op. cit.*, (127), 17.

¹³² Venn, *op. cit.*, (26), **5**, 234.

Of all the applicants, the Rev. John Walker was probably the one with the most contemporary renown, as well as being the oldest. He and the other Irish candidate, William Thynne, were also the only men to apply for both the Greek and the mathematics professorships. Born in 1768, Walker had obtained his B.A. from Trinity College, Dublin, in 1790, before proceeding to a fellowship the following year.¹³³ Although ordained a priest in the Church of Ireland, he underwent a change in his religious opinions around 1804 which resulted in his expulsion from the college. He began to preach strong Calvinistic doctrines while publishing works in classics and mathematics, such as editions of Livy (1797) and Euclid (1808).¹³⁴ Moving to London in 1819, he would certainly have welcomed the establishment of the secular university, and indeed was the first to apply for the mathematics professorship then. Unsuccessful in both attempts, his failure in the latter was mollified by his appointment in October as headmaster of the university's school,¹³⁵ a post he held for just one term before returning to Dublin, where he died in 1833.¹³⁶

Walker's compatriot, William Shortt Thynne, was some forty years his junior, having graduated from Dublin University only that year.¹³⁷ Like Walker, his attentions had been equally divided between mathematics and the classics, but his publications in the former department were as yet non-existent, although he had apparently "proceeded some distance in preparing a treatise on Algebra"¹³⁸ - which would not appear for another eighteen years.¹³⁹ His *Compendium of Logic* (1827), was apparently "spoken favourably of by the Fellows of his College and is in esteem and demand among the students",¹⁴⁰ but this was largely irrelevant since logic was wholly separated from mathematics at this time. His failure to obtain either the Greek or the mathematical chair is probably explained by the impression, which is often conveyed in an application for multiple positions, of inadequate qualification for either.

¹³³ *op. cit.*, (117), 586.

¹³⁴ Alfred Webb, *A Compendium of Irish Biography*, (Dublin: M. H. Gill and Son, 1878), 544.

¹³⁵ H. J. K. Usher, C. D. Black-Hawkins and G. J. Carrick, *An Angel Without Wings: The History of University College School 1830-1980*, (London: University College School, 1980), 15.

¹³⁶ Henry Boylan, *A Dictionary of Irish Biography*, 2nd edition, (Dublin: Gill and Macmillan, 1988), 393.

¹³⁷ *op. cit.*, (117), 562.

¹³⁸ UCC, No. 2187, William Thynne to Council, 9 Sept. 1831.

¹³⁹ William Thynne, *The Theory of Algebraic Equations: a chapter of elementary algebra*, (Cambridge: J. & J. J. Deighton, 1849).

¹⁴⁰ *op. cit.*, (138).

Another applicant who was clearly below the standard required by the council was Eneas McIntyre. A former student of King's College, Aberdeen,¹⁴¹ he had been teaching mathematics and classics at various London private schools since his graduation in 1813. Not only do his letters suggest that his teaching experience was at a somewhat more elementary level than was required by the university, but also a period of nearly twenty years had elapsed since his last active study of the higher branches of mathematics. Maybe because of these deficiencies, he suggested that "if the council should wish at present to fill the chair provisionally, I would readily accept it and may prefer accepting it in that way; resolved to use my best exertions in the meantime, & happy to resign the charge into more efficient hands".¹⁴² It is needless to say that the council did not avail themselves of this proposal.

Two other candidates, George Laing and "Mr. Dowling", of whom very little information can be determined, seem to have been similarly unsatisfactory. Laing was not even a university graduate, having studied for "some years with Dr. Kelly of Finsbury Square",¹⁴³ while Dowling's qualifications, by virtue of their absence from any source, must have been equally unimpressive. A man with better credentials was the Frenchman Guinibert Debac, a graduate of the renowned École Polytechnique in Paris. Although he had been a successful private mathematical tutor for the previous thirteen years, "4 years in Brussels and 9 in England",¹⁴⁴ Debac had yet to achieve any fame or recognition as a mathematician, despite being thirty-eight years of age. Indeed, he had deliberately abstained from publishing any original works on mathematics "which," he said, "already abound".¹⁴⁵ This may not have been the most advisable attitude for a potential professor of a university still endeavouring to establish its academic reputation.

Of a similar age to Debac was the Rev. John Buck, another intriguing character, although again wholly unsuitable for the post. Born in 1792, he had been a cadet at the Royal Military Academy in Woolwich before leaving for India in 1808 to serve in the Bengal Army. After rising to the rank of lieutenant, he resigned his commission in 1819, returning to England and entering Queens' College, Cambridge, with the intention of taking holy orders. Being ordained in 1824, he received an undistinguished B.A. the

¹⁴¹ Peter John Anderson, (ed.), *Roll of Alumni in Arts of the University and King's College of Aberdeen, 1596-1860*, (Aberdeen: Printed for the University, 1900), 118.

¹⁴² UCC, No. 2189, Eneas McIntyre to Thomas Coates, 11 Sept. 1831.

¹⁴³ *ibid*, No. 2194, George Laing to Thomas Coates, 13 Sept. 1831.

¹⁴⁴ *ibid*, No. 2248, Guinibert Debac to Council, [26 Sept. 1831].

¹⁴⁵ *ibid*.

following year. His mathematical output was limited to a pamphlet on the solution of equations¹⁴⁶ and an edition of Diophantus of which "the greatness of the expense has alone deferred its appearance before the public".¹⁴⁷ However, Olinthus Gregory observed that the pamphlet was "of no great merit",¹⁴⁸ and, noting that the work on Diophantus had never appeared, remarked "*I never expected that it would*".¹⁴⁹ Indeed, Gregory's "testimonial" probably ensured Buck's swift rejection, concluding with the opinion that "unless he be greatly changed..., he cannot possess that stability of character which would render it a desirable thing for him to be appointed to a professorship in the University of London."¹⁵⁰

Of the many words which come to mind in reviewing the candidates for the 1831 competition, one in particular encapsulates their overall quality: mediocre. The competitors were either too young and inexperienced, or were mature teachers either at the wrong level or with no adequate evidence of original publications. In certain cases the applicants were disadvantaged by the generality of their education or being undecided whether to specialise in mathematics or classics. In general however, none of the above applicants, irrespective of age or ability, displayed any *potential* for future eminence in the way De Morgan had so effectively done three years previously. The one exception to this was John Radford Young, who not only had a fine record of tuition and publication, but would soon go on to distinguish himself by his original research. Once again, his rejection is singularly difficult to adequately explain, but perhaps the most likely reason was the noticeable tendency of the selectors when choosing a mathematical professor to favour a Cambridge education.¹⁵¹ This was certainly understandable since the undergraduate course at Cambridge was, after all, more mathematically-oriented than at any other university. But no Cambridge graduate of any distinction had come forward as a candidate - not until the council received one final letter of application from a Mr. G. J .P. White of Trinity College, Cambridge.

Virtually no information exists concerning the life and background of George James Pelly White. All that is known is that he was born in London, and, after attending a school in

¹⁴⁶ John Buck, *A New, General, and Algebraical Solution of the Higher Orders of Equations: with solutions of equations, to the tenth degree inclusive*, (London: Carpenter and Son, 1823).

¹⁴⁷ UCC, No. 2186, John Buck to Thomas Coates, 5 Sept. 1831.

¹⁴⁸ *ibid*, No. 2205, Olinthus Gregory to Thomas Coates, 19 Sept. 1831.

¹⁴⁹ *ibid*.

¹⁵⁰ *ibid*.

¹⁵¹ Notice the dominance of wranglers in the shortlists for the competition of 1828.

Isleworth, Middlesex, entered Trinity College in February 1825.¹⁵² His age at this point is given as eighteen,¹⁵³ which makes him approximately the same age as De Morgan, being born either in 1806 or early 1807. Whether the two men were acquainted at Cambridge is unknown, but certainly possible, since they would have been resident at the same college for two years. White also had many of the same teachers, his personal tutor being William Whewell.¹⁵⁴ In January 1829, two years after De Morgan, he sat the Tripos, coming out as sixth wrangler. What he did for the next two years is unknown but, since he did not obtain a fellowship, it seems likely that he left Cambridge immediately after his graduation.¹⁵⁵

His somewhat late entrance into the competition at London University was possibly due to an unawareness of its occurrence because of his absence from the academic community, and it was presumably advice from his former tutor which led him to put his name forward. His introductory letter began with the words: "On the recommendation of Professor Whewell I beg leave to offer myself as a candidate for the vacant Chair of Mathematics in the London University & to lay before you the enclosed proofs of my qualifications."¹⁵⁶ These testimonials comprised eleven letters of recommendation (no longer extant) from scholars such as Whewell, Higman, Peacock and Airy, which immediately bring to mind the excellent references these men had provided for De Morgan in 1828. Yet, irrespective of the content of these letters (now unavailable), the mere names of the referees alone would have been impressive enough to the selectors in a competition notably bereft of endorsements from high-ranking men of science.

More interestingly, as far as the council was concerned, White represented the closest substitute for De Morgan that it was possible for them to obtain at that time. He was a high wrangler, from the same college, with the same tutors and similar endorsements. Moreover, he was of roughly the same age, with no publication record, perhaps no teaching experience either, but, as his testimonials would no doubt have emphasised, a good deal of mathematical potential. But whereas the election of De Morgan had been a calculated risk from a selection of competitors of roughly equal merit, George White was quite clearly far superior in mathematical qualifications to any of his co-applicants.

¹⁵² Walter William Rouse Ball & John A. Venn (eds.), *Admissions to Trinity College, Cambridge*, 4, (London: Macmillan and Co., 1911), 251.

¹⁵³ Venn, *op. cit.*, (26), 6, 436.

¹⁵⁴ Rouse Ball & Venn, *op. cit.*, (152).

¹⁵⁵ He proceeded to an M.A. in 1832.

¹⁵⁶ UCC, No. 2254, George James Pelly White to Council, [4 Oct. 1831].

Indeed, having seen their overall quality, we can appreciate how conspicuous his application must have appeared and how obvious a choice he must have seemed. Consequently, on 19 October 1831, at the meeting immediately following the receipt of his letter of application, White was unanimously elected the new professor of mathematics,¹⁵⁷ which he accepted "without hesitation".¹⁵⁸

3.2.2 The new mathematics course

With only a fortnight before the university was due to re-open for the new session, White was clearly left with very little time to put together a new mathematics course. Yet, considering the short notice he would have been given, the syllabus he produced was not the hurried amalgam of topics one would perhaps have expected, but a considered and carefully structured programme of study. Indeed, it appears to have been the result of some considerable thought and effort *prior* to his election, and, given that it was submitted for the council's perusal on 17 October, presumably acted as another testimonial in his favour. Furthermore, it does not seem to have been influenced by the syllabus previously employed by De Morgan, of which White may well have been unaware. Consequently, when the university opened for its fourth session in November 1831, the plan of its mathematical tuition had been substantially re-arranged under the following scheme:

Subjects of Lectures for the First Division

- Junior Class - Arithmetic, Euclid, Arithmetical Algebra, Geometrical Trigonometry.
- Senior Class - Conics, Solid Geometry, Spherical Geometry & Trigonometry, Algebra, Elements of Analytical Geometry, & of Differential & Integral Calculus.

Subjects of Lectures for the Second Division

- Junior Class - Arithmetic, Euclid, Algebra, Analytical Geometry, Trigonometry.
- Senior Class - Theory of Equations, Analytical Geometry continued, Differential & Integral Calculus, Solid Geometry, Spherical Trigonometry, Elements of Analytical Geom. of 3 dimensions, Elements of Calculus of Differences.
- 3rd Class - Development of the preceding subjects, Analytical Notation, Differential & Integral Calculus, Calculus of Differences, Calculus of Functions, Calculus of Variations, Chances.¹⁵⁹

¹⁵⁷ Committee of Management Minutes, vol. I, f.23.

¹⁵⁸ UCC, No. 2242, G. J. P. White to Thomas Coates, 21 Oct. 1831.

¹⁵⁹ *ibid*, No. 2255, Mathematical course outline by G. J. P. White, 17 Oct. 1831.

The most noticeable characteristic of the new syllabus, in comparison to its predecessor, was its structure. Although under De Morgan students had been free to enter at any level, subject to adequate preparation beforehand, the course then offered had been perfectly linear, beginning in the lower junior class and extending to the higher senior. In contrast, White offered his students the choice of *two* totally separate mathematics courses (or divisions, as they are confusingly termed above): a more elementary programme lasting two years, and another more technical course which lasted for three. Hence, whereas De Morgan's students had been taught in four groups, under White there were five, since his advanced division was split into three classes. Moreover, as they were intended for two distinct categories of mathematics student, White's two courses were distinguished not only by the techniques taught, but also by what knowledge the students could expect to have obtained by their completion:

The Students of the first Division who are masters of the subjects of the first Class only, will find themselves capable of understanding the principles of Mechanics, Optics, Hydrostatics &c, & the machines & instruments commonly used - in fact sufficient for most of the purposes of a practical life. The complete course will enable them to understand the principles of Dynamics, of plane & physical Astronomy, Mineralogy &c. In the second Division the methods recommended will be more analytical & scientific. The lectures of the two first Classes will comprehend the course commonly delivered in the lecture rooms at Cambridge & will enable the student to read most of the modern scientific treatises on Natural Philosophy & to pursue his researches in it. The lectures of the third Class are intended to extend the Student's views of the principles of Mathematics & to lead him to the very summits where he can command the sublimest discoveries of Physical Astronomy.¹⁶⁰

Yet whether his students reached the end of the course or not, White assured them that those who chose to conclude their mathematical studies at the end of any session "will find them complete as far as they go".¹⁶¹

Because of the inclusion of a third class in his higher course, which he taught on Tuesday and Thursday evenings, White's weekly timetable involved a total of 17¼ hours teaching - an increase of two hours on De Morgan's maximum workload. This arrangement lasted throughout his term as professor, although in the 1835-36 session, probably because of inadequate numbers, no third class was offered.

¹⁶⁰ *ibid.*

¹⁶¹ *University of London. Session 1831-32*, (London: Richard Taylor, 1831), 5.

First Division (Junior Class):	Tues, Thurs	8.45 - 10.00
	Saturday	9.00 - 10.30
First Division (Senior Class):	Tues, Thurs	2.15 - 3.15
	Saturday	11.00 - 12.30
Second Division (Junior Class):	Mon, Weds, Fri	8.45 - 10.00
	Saturday	9.00 - 10.30
Second Division (Senior Class):	Mon, Weds, Fri	2.15 - 3.15
	Saturday	11.00 - 12.30
Second Division (Third Class):	Tues, Thurs	6.15 - 7.45
	Saturday	11.00 - 12.30

The fees levied by White for his courses were identical to those of De Morgan: £7 for his first division and £6 for the second. For his first year in office, no exact figures are available concerning his class sizes, but, due to the general depressed state of the university's fortunes, they would almost certainly have been disappointing. During 1832-33, although the precise number of students is again unrecorded, total receipts for the mathematical classes appear to have been just under £240, from which he derived an income of a mere £169 6s 8d.¹⁶² Given also that in that year his first division amounted to just 30 students,¹⁶³ this makes the total number of mathematics students no more than 35. Matters improved considerably the following year, with an aggregate of 55 students, although this was to be the highest attendance his lectures would attract, with numbers falling to 46 and 40 in the following two sessions. Table 3 gives an indication of the number of students attending White's two divisions, together with the fluctuations in the professor's income. When it is remembered that, even deducting the university's share of his fees, De Morgan was earning in excess of £400 per session a few years previously,¹⁶⁴ it is clear that White's emoluments, though adequate, were far from substantial.

As with De Morgan's tuition during the preceding three years, the only satisfactory way to form some idea of what White actually taught his classes is to study a selection of the examination papers he set at the close of each session. From these, we know that tuition for his first division, being designed for those for whom mathematics was not a principal subject of study, was more tailored to practical applications such as business, economics

¹⁶² UCC, No. 2865, G. J. P. White to Thomas Coates, 4 Feb. 1833.

¹⁶³ UCC, No. 2783, G. J. P. White to Thomas Coates, 13 Nov. [1832].

¹⁶⁴ University of London. Fees Journal. Session 1828-29, ff. 7, 13, 22; Session 1829-30, ff. 45, 51, 56, 67, 76; Session 1830-31, ff. 102, 115, 120, 124.

Table 3

Mathematical Classes 1832-36

SESSION	TOTAL No. OF STUDENTS	GROSS	WHITE'S INCOME
1832-33	≈35 (30 × £7, 5 × £6)	≈£240	£169 6s 8d
1833-34	55 (35 × £7, 20 × £6)	£364	£242 13s 4d
1834-35	46 (27 × £7, 19 × £6)	£303	£202
1835-36	40 (21 × £7, 18 × £6, one exemption)	£255	£177 10s

or design. Hence, although the junior class in this division studied geometry from Euclid, the questions White set them were not entirely abstract. For example: "There are three places, A, B, C; the distance between A and B is 10 miles, between A and C 17, between B and C 21: find, by a construction, the angle which A and B subtend at C."¹⁶⁵ In algebra too, the questions, while certainly of an abstract nature, were clearly posed with the real world in view: "Show that P£ will amount to $P(1.04)^n$ in n years at 4 per cent per annum compound interest: and calculate the amount of £50 in twenty years."¹⁶⁶

Questions answered by the senior class of this first division were naturally more advanced, being particularly dominated by analytical geometry and the calculus, although in terms of difficulty problems rarely exceeded finding normals, tangents or areas under curves. However, despite the prevalence of more abstract course material, problems were occasionally presented in practical terms, such as the following max/min question:

A person engages workmen to build a coach, on condition that they shall each have the use of it for m days after it is completed. How many workmen must he employ in order that he may get possession of it in the shortest time? it being supposed that the work would occupy a men n days.¹⁶⁷

The class's study of spherical trigonometry also involved a mixture of the purely abstract and more utilitarian problems, such as: "Explain fully the method of making a map of a

¹⁶⁵ *University of London. Faculty of Arts. Distribution of the Prizes and Certificates of Honour. Session 1835-36. With the examination papers.* (London: Taylor and Walton, 1836), 64.
¹⁶⁶ *ibid*, 73.
¹⁶⁷ *ibid*, 80.

large track of country."¹⁶⁸ This emphasis on mathematical utility was increased with the addition to the syllabus of "Principles of Linear Perspective"¹⁶⁹ from 1834, which would, for example, enable students to "Represent in perspective a room having on one side a book-case with open doors."¹⁷⁰

The subject matter taught in White's second division, being designed for the purely mathematically-minded, was generally more high-powered. Since the students taking this course would be more able than those in his first division, White was able to cover the material in greater depth; for example, a question in one of his papers reveals some assumed knowledge of geometrical systems other than Euclid's: "State the geometrical method by which Legendre attempts to get over the difficulty of parallel lines, and point out its fallacy."¹⁷¹ He was also able to proceed at a quicker pace, so, for example, the junior class of this division progressed as far as the rudiments of analytical geometry, a subject not tackled until the senior class of the first division. The middle class of this division also proceeded further than its counterpart, being examined on all of the subjects listed above as well as the use of logarithms, the binomial theorem, and the general expansion and summation of series, which formed the basis of their introduction to the differential and integral calculus.

White's elite third class, although very sparsely attended, would have provided the student with the most advanced mathematical tuition hitherto obtainable in the university, higher even than that previously offered by De Morgan. Surviving examination papers reveal its chief components to have been further developments of calculus-related topics such as differential equations and the calculus of variations. The use of infinite series was also investigated further, with subjects including Lagrange's theorem and cases of failure of Taylor's theorem - material which would not look out of place in a course on real analysis today. A separate, and innovatory, constituent was the introduction of probability theory¹⁷² into the course which, after the usual questions about balls from bags, advanced to problems of a far from elementary nature: "Supposing the skill of a superior player,

¹⁶⁸ *ibid*, 82.

¹⁶⁹ *University of London. Session 1834-35. Faculty of Arts*, (London: Richard Taylor, 1834), 3-4.

¹⁷⁰ *University of London. Midsummer Examination - Session 1834-35. Faculty of Arts. Mathematics - Second Class*, Question 21.

¹⁷¹ *op. cit.*, (165), 65.

¹⁷² It will be recalled from his original syllabus that De Morgan had intended to teach this subject but, during the sessions 1828-31, never did so.

compared with that of others, to vary from $\frac{3}{2}$ to infinity; find the chance that he will win two games in succession from a stranger."¹⁷³

Though the details of White's mathematical course may have differed somewhat from that of his predecessor, certain aspects of their tuition were similar. Firstly, both strictly adhered to the university's policy on the manner in which the tuition was administered, with White emphasising the fact that, not only was there "a direct communication between the Teachers & Pupil, [but] there are written exercises & constant oral examinations".¹⁷⁴ Like De Morgan, he devoted his Saturday classes to these examinations and also took regular opportunities "to propose for solution a variety of problems on every branch of the subject"¹⁷⁵ from which he derived his examination questions. Furthermore, although their way of presenting their syllabuses contrasted considerably, in essence the material they offered was basically the same. Indeed, De Morgan's junior and senior classes could be seen as analogous to White's first and second divisions, the lower options both containing "what is most essential for those who are intended for practical professions, such as Civil Engineers, &c",¹⁷⁶ and the more advanced courses providing the student with the higher mathematics required for the study of natural philosophy.

Yet these similarities merely concerned the overall structure and organisation of their respective courses, correspondences which were occasioned purely by the necessity for both men to conform to the university's teaching requirements, as previously laid down by the council. When we turn to matters over which they would have had direct control, such as the actual course content, the real differences between the two men's methodologies emerges. The first is with regard to examinations, with both revealing differing attitudes on how they believed their students should be assessed. De Morgan clearly considered that the student should be tested on all of his mathematical knowledge at one time, hence his papers for each class contained questions on a selection of the topics each group had studied during the preceding session. In contrast, White set each of his classes a number of separate papers on various topics covered in that year's course; so, for example, the junior class of his first division would receive three papers, one on

¹⁷³ *University of London. Midsummer, 1832. Mathematics. Final Examination - (Problem Paper)*, Question 15.

¹⁷⁴ *op. cit.*, (159).

¹⁷⁵ *ibid.*

¹⁷⁶ *Second Statement by the Council of the University of London, Explanatory of the Plan of Instruction*, (London: Richard Taylor, 1828), 42.

Euclid, one on arithmetical algebra, and one on commercial arithmetic and elementary trigonometry.

The questions set in these examinations reveal a further disparity between material covered by De Morgan and his successor. The most apparent difference here is that White seems to have taught a wider variety of subjects than De Morgan, as witnessed by his introduction of perspective and probability theory into the examinations. Yet White introduced nothing which had not been specified by De Morgan in his original course outline of 1828. For example, another ingredient of White's initial plan of instruction was his intention "to point out the fallacies of opponents, [and] to give the history of the great divisions of mathematics & of the masterminds who have advanced them".¹⁷⁷ This again had been one of De Morgan's early aims but, judging from an absence of relevant questions on his exam papers, it seems that lack of time prevented its consideration in his classes. Under White however, while the depth of investigation cannot have been very deep, mathematical students appear to have been given at least some introduction into the history and philosophy of their subject:

Give a brief account of the Mathematicians who lived before the destruction of the Alexandrian school.¹⁷⁸

What is the numeral system now in use? and whence was it derived? Does it in any respect resemble that of the Greeks or Romans?¹⁷⁹

On what foundations does a pure science rest? Is Euclid's system of geometry a perfect specimen of a pure science?¹⁸⁰

Since we have no sources from which to judge their styles of tuition other than examination papers, it is impossible to say who was the 'better' teacher. It is true that White was teaching material of a higher level of difficulty to his very highest class than De Morgan's higher senior had received by 1831; yet, while we should not negate White's achievement, it would not have been possible, initially at least, without the increase in the students' ability initiated by De Morgan. When it is remembered that De Morgan's earliest

¹⁷⁷ *op. cit.*, (159).

¹⁷⁸ *University of London. Midsummer Examination - Session 1834-5. Faculty of Arts. Mathematics - Junior Class. Second Division*, Question 1.

¹⁷⁹ *University of London. Session 1832-33. Mathematics. First Class. Examination for Prizes and Certificates of Honour*, Question 1.

¹⁸⁰ *University of London. Session 1832-33. Mathematics. First Class - First and Second Divisions. Examination for Prizes and Certificates of Honour*, Question 1.

classes were of a substantially lower ability than his later ones, White may have been, at least in part, reaping the benefits of De Morgan's earlier instruction. White's lecturing style also appears to have been more conservative than that of De Morgan with regard to the use of models and visual aids for the teaching of geometry. Later recalling the "mathematical apparatus constructed by me during my occupation of the Professorship...[including] some diagrams of Euclid painted on cotton," De Morgan noted "that Mr White did not use these".¹⁸¹

However, White does seem to have been more imaginative in the matter of posing interesting problems for his students to solve. Take for example a (very topical) question from a paper of 1832: "If one of the candidates at an election had had 40 more of the votes which were given, the numbers would have been as 3 to 2, but if he had had 60 less they would have been as 1 to 2: did he succeed?"¹⁸² Here White demonstrates the ability to present a simple problem in an intriguing form designed to arouse the interest of the student and make its solution more intelligible. For this reason, it is surprising that he published no textbooks for his students as De Morgan had done, given that he would surely have been capable of doing so. Yet it would appear that he definitely entertained such an intention: in a catalogue of the university's publisher, Taylor and Walton, from March 1835, a book entitled *Arithmetical Algebra* by G. J. P. White is claimed to be in preparation¹⁸³ - it never appeared.

The formation of an adequate evaluation of the overall achievement of White as a professor of mathematics is difficult for many reasons. The period of his tenure, although longer than De Morgan's initial term as professor, is still too brief to be able to detect any radical improvement or decline in the general standard of tuition on the part of the professor, and attainment on the part of the students. Consequently, to conclude from the decline in his class figures that his teaching methods were inadequate or unpopular would be pure speculation, especially when it is recalled that the university was undergoing a period of extremely low student numbers at this time. It should also be added that sources concerning this period are excessively scarce and of varying reliability, so, for example,

¹⁸¹ UCC, No. 3768, De Morgan to Charles C. Atkinson, 10 Oct. 1836.

¹⁸² *University of London. Midsummer, 1832. Mathematics. First Class - First and Second Divisions*, Question 6. (The answer is no!)

¹⁸³ *Works in Mathematics, Natural Philosophy, History, &c. printed for Taylor and Walton. booksellers and publishers to the University of London*, List No.3, March 1, 1835, (London: Taylor and Walton, 1835), 1.

neither of the two references containing biographical information on White make any reference to his having been a professor at all.

Had he remained at the university for over thirty years, or attained the eminence which Augustus De Morgan would eventually achieve through original publications, this thesis could well have been concerned with the life and career of George James Pelly White. Yet within five years of his appointment, White's career was at an end, his connection with university education permanently severed, and De Morgan had returned to his former position. How and why this happened will follow, but, before we can discuss the circumstances of 1836, we must first consider events within and without the university during the five years of White's professorship.

3.2.3 The university situation

With the departures of Horner and Pattison in July 1831 it had finally become possible to restore some degree of stability to the university. The first step towards this goal was the much needed reform of its discredited constitution. On 10 August, the council initiated this process with the appointment of seven of its members to form a new Committee of Management to administer the university's affairs.¹⁸⁴ This institution of a more streamlined system of government resulted not only in more efficient administration but also "eliminated those violent fluctuations in policy which arose from the irregular appearance on critical occasions of members who were normally absent".¹⁸⁵ The role of the full council was now relegated to meeting once a month to endorse its committee's decisions. This new arrangement was approved by the annual general meeting of the university's proprietors on 29 February 1832.¹⁸⁶

At a second meeting, held three days later, the proprietors also resolved "That it is expedient to establish a *Senatus Academicus* for conducting the discipline of this University; and that it be referred to the Council, in concurrence with the Professors, to consider a plan for that purpose".¹⁸⁷ Although subordinate in authority to the committee of management, this senate, to which all academic staff were automatically affiliated, finally gave professors the collective influence over university matters which had

¹⁸⁴ Council Minutes, vol. II, f.320.

¹⁸⁵ Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 213.

¹⁸⁶ *University of London. Wednesday, 29th February, 1832. The Annual General Meeting of Proprietors...* (London: Richard Taylor, 1832), 6.

¹⁸⁷ *ibid*, 16.

previously been denied them. In addition, its creation drastically improved the means of communication between the ruling body and their professors, with relations being further enhanced by the inclusion of a member of the committee of management as its president. With its ratification by both the council and the proprietors, the professorial senate was finally established in August 1832.¹⁸⁸

As a further concession to professors' earlier demands, the senate was divided into three faculties, arts, law and medicine¹⁸⁹ - although from 1833, the faculties of arts and law were combined. Each faculty elected a new Dean every session who served as chairman and secretary of his faculty and a further medium of communication between the senate and the committee of management.¹⁹⁰ One of the principal functions of the new senate was the maintenance of discipline among the students, a matter on which both the council and the professors had been embarrassingly impotent under the previous constitution. In particular, the professors of mathematics, Greek and Latin, having the most contact with the youngest students, were given the power "to call a Student in any of their Classes before them; and to admonish him, or to suspend him from attendance on any or all of their Classes for any time not exceeding a week".¹⁹¹ For the purpose of expulsion a special Court of Discipline, consisting of the committee of management and the deans, would be convened.¹⁹²

The other main province of the senate concerned the appointment of new professors. Henceforth, in the eventuality of a professorship becoming vacant, "the Council shall, before they fill up the vacancy, communicate to the Senate the names of all the candidates for the Office, with all their testimonials; and the Senate shall report their opinion thereon to the Council; and no appointment shall be made until the Report of the Senate has been received".¹⁹³ Jurisdiction over the behaviour of professors was also given to the senate and again, although ultimate authority was still vested in the council and committee of management, in all matters, even alleged incompetence and conduct unbecoming, they would "not decide upon the case until they have received the Report of the Senate thereon".¹⁹⁴

¹⁸⁸ Council Minutes, vol. II, ff.364-8.

¹⁸⁹ *University of London. Regulations for the Discipline of the University*, (London: Richard Taylor, 1832), 2-3.

¹⁹⁰ White, as professor of mathematics, was dean of the faculty of arts for the session 1834-35.

¹⁹¹ *op. cit.*, (189), 6.

¹⁹² *ibid*, 3.

¹⁹³ *ibid*, 4.

¹⁹⁴ *ibid*, 5.

The university's improved constitution did much to ameliorate the tensions which had plagued the institution since its inauguration. However, this was not the only problem faced by those concerned with its welfare in the early 1830s. Its disturbing financial situation intensified as student numbers continued to fall, from 516 in 1830-31¹⁹⁵ to a mere 400 in 1831-32.¹⁹⁶ If White's income from his mathematical classes appeared disappointing, other professors' emoluments became almost non-existent. By November 1831, attendance on the natural philosophy course had deteriorated to an alarming level with Lardner reporting that "only 8 pupils had entered to his Class".¹⁹⁷ Not surprisingly, one month later, "in consequence of the inadequate remuneration which the Class affords",¹⁹⁸ he finally resigned his professorship. He was replaced in January 1832 by William Ritchie,¹⁹⁹ the Scottish physicist who had originally competed for the chair of elementary mathematics in 1827.

With such an alarming erosion in student numbers, the university's closure was becoming an increasingly conceivable possibility: "I take it for granted," wrote one of the proprietors in the autumn of 1831, "the stoppage for want of funds will occur not later than February."²⁰⁰ Yet, despite a deficit of nearly £3000, the university somehow managed to continue, although by February 1833, the council were forced to admit that unless substantial changes were effected "the Institution cannot reopen upon its present footing".²⁰¹ Yet it was to be the constitutional changes already instituted by the council which were to provide the impetus for the university's recovery, the source of its regeneration coming from none other than those who benefited most from them: the professors.

Whereas a year or so earlier, the professoriate had been alienated from the council with no influence on university policy or security of tenure, their recently improved position now gave them an incentive to assist in its rejuvenation. Prompted by the current financial

¹⁹⁵ *University of London. Annual General Meeting of Proprietors held on Wednesday, the 23rd of February, 1831.* (London: Richard Taylor, 1831), 7.

¹⁹⁶ *University of London. Report of the Council to the Proprietors. February 1833.* (London: Richard Taylor, 1833), 8.

¹⁹⁷ Committee of Management Minutes, vol. I, f.29.

¹⁹⁸ Council Minutes, vol. II, f.329.

¹⁹⁹ *ibid*, f.339.

²⁰⁰ Katharine M. Lyell, (ed.), *Memoir of Leonard Horner*, (London: Women's Printing Society Ltd., 1890), vol. I, 259.

²⁰¹ *op. cit.*, (196), 11.

crisis, the professors published a statement in which they assured the council "of their unabated zeal, and of their willingness to expend their time and labour for the Institution to which they have attached themselves".²⁰² To prove their commitment, the professors unanimously proposed to guarantee an income of £3181 to the university for the session 1833-34.²⁰³ With the addition of a loan of £4000 to cover their debts, plus a mysterious donation of £1000 "by an unknown friend, under the name of a 'Patriot',"²⁰⁴ in February 1834 the university was finally able "for the first time, out of its proportion of the fees, to meet the annual ordinary expenses of the Institution".²⁰⁵

Another factor in the gradual improvement of the university's fortunes had been the success of a school recently founded in connection with it. Its establishment had been suggested by *The Times* as far back as September 1829,²⁰⁶ with the council indicating an interest in the idea in February 1830.²⁰⁷ They had given Leonard Horner the task of finding a headmaster, which he did in the form of the Rev. Henry Browne M.A. of Corpus Christi College, Cambridge, who promptly issued a prospectus in which the dual benefits of the school were elucidated: "The advantage of such a school would be, that it would promote the welfare of the University by furnishing its Latin, Greek, English, and Mathematical Classes, with a regular supply of Pupils, qualified to enter on the academical course with due effect; and that it would extend the objects of the University, by enabling parents to give their sons, at a very moderate expense, the rudiments, as well as the completion, of a sound, liberal education, without the necessity of sending them from home".²⁰⁸

The *London University School* duly opened on 1 November 1830 at No.16 Gower Street²⁰⁹ with 58 pupils, but by February 1831, that number had doubled to 116 which, it was reported, "is very nearly as many as the House can receive".²¹⁰ By the start of its second session in October 1831, Browne had been replaced by the Rev. John Walker, the

²⁰² *University of London. Annual General Meeting of Proprietors held on Wednesday, the 27th of February, 1833.* (London: Richard Taylor, 1833), Appendix, 5-6.

²⁰³ *University of London. Report of the Council to the Proprietors. 26th February 1834.* (London: Richard Taylor, 1834), 3.

²⁰⁴ *ibid.*, 4.

²⁰⁵ *ibid.*, 3.

²⁰⁶ *The Times*, 29 Sept. 1829, 2d-e.

²⁰⁷ *University of London. Annual General Meeting of Proprietors held on Wednesday, 24th February, 1830.* (London: Richard Taylor, 1830), 10; *The Times*, 25 Feb. 1830, 5a.

²⁰⁸ Usher, Black-Hawkins & Carrick, *op. cit.*, (135), 10.

²⁰⁹ Now numbered 32.

²¹⁰ *op. cit.*, (195), 7.

non-conformist Irish minister recently rejected for both the chairs of mathematics and Greek at the university. Yet this arrangement was similarly cut short by his premature resignation that Christmas. It was at this point that the council took the opportunity to assume direct control by bringing the school into the university building itself where it re-opened in January 1832. In addition, the council appointed two of its professors to serve as joint headmasters.²¹¹ The first was Thomas Hewitt Key (1799-1875), the energetic professor of Latin, who would remain at the school until his death in 1875. The second was the newly-appointed professor of Greek, Henry Malden (1800-1876).

Malden had succeeded George Long in the Greek chair in September 1831 while the competition for that of mathematics had been at its height.²¹² Indeed, just as White appears to have been a duplicate of De Morgan in terms of educational background and qualifications, Malden seems to have been a similar replica of Long, with both men being the same age, having entered Trinity College Cambridge in 1818 and graduated four years later with honours in classics.²¹³ Following their election to fellowships, Long had moved to Virginia while Malden was recommended for the rectorship of the newly-founded Edinburgh Academy, which he failed to obtain.²¹⁴ Like Long, Key and De Morgan, Malden also took an active interest in the activities of the Society for the Diffusion of Useful Knowledge, for whom he wrote a *History of Rome to B.C.390* in 1830. A placid and unassuming man, he was also to remain at the university for the rest of his life, although he resigned his headmastership in 1842.

In its new location under the joint supervision of Key and Malden, the school flourished rapidly with its pupil population rising from 80, at Easter 1832, to 140 by the summer, and 192 by Christmas. By February 1833, the figure stood at 249 and was to continue to increase - though not quite so dramatically - for some considerable time.²¹⁵ As *The Times* acknowledged that year: "The junior school has succeeded beyond any expectation which could have been entertained of the attempt to establish it two or three years ago."²¹⁶ Indeed it was prospering at a time when progress in the rest of the university was essentially stationary. A major reason for its success was its innovative style of operation. For example, there were no compulsory subjects - although, in order to proceed to the

²¹¹ *op. cit.*, (186), 4-5.

²¹² Committee of Management Minutes, vol. I, f.17.

²¹³ Venn, *op. cit.*, (26), 4, 299.

²¹⁴ *D.N.B.*, 35, 417.

²¹⁵ *op. cit.*, (196), 9.

²¹⁶ *The Times*, 21 May 1833, 5c.

university, pupils had to take Greek, Latin and mathematics - and, of course, no religious instruction.²¹⁷ But perhaps its most progressive feature, and a further reason for its popularity, was its complete rejection of corporal punishment.²¹⁸

The final and probably most significant original feature of the school, was its mode of tuition:

In the method of teaching there is nothing which is put forward as original or new; but in following the usual methods, the Professors take care that the understanding of their Pupils shall be exercised by frequent and close questioning. The part of the system which seems most peculiar, is, that to the younger Pupils the greatest part of their instruction is communicated orally, and their memory is less burthened than in common Schools with lessons to be learnt by rote from books. For example, they are taught Geography, not by learning lists of names, but by the teacher pointing out to the Class the situation of places on large and distinct Maps, and questioning them afterwards.²¹⁹

A total of eleven masters (of whom four were employed full-time) assisted the two professors in the instruction of the classes. In terms of subjects taught, the emphasis was on science and languages, with most of the pupils taking Latin, and many also studying French and German. Drawing was also a subject to which much attention was given.²²⁰ Mathematics was strongly represented and, as shall be seen, many pupils were later to distinguish themselves at a higher level in De Morgan's classes and beyond. The quality and range of tuition - strikingly ahead of its time - soon proved very effective. Within a matter of years, it was providing a steady supply of high-quality students for the university classes and would eventually number many distinguished names among its former pupils, including Stanley Jevons, Joseph Chamberlain and Karl Pearson, as well as all three of De Morgan's sons.

The general upturn in the university's prospects around 1833 led to the revival of calls for the conferment of a charter to enable it to award degrees. Since its foundation in 1826, the university had consistently been denied legal recognition, although charters of incorporation had subsequently been granted to both King's College, London, and St.

²¹⁷ Usher, Black-Hawkins & Carrick, *op. cit.*, (135), 19.

²¹⁸ *ibid*, 15.

²¹⁹ *op. cit.*, (196), 9.

²²⁰ Bellot, *op. cit.*, (185), 170.

David's College in Lampeter.²²¹ On 10 February 1831, it was reported that a charter "which now only awaits the Royal signature, is to be granted to the University of London, bestowing on this establishment all the privileges and powers at present enjoyed by the most favoured of our universities, the granting of degrees in theology alone, for the present, being excepted".²²² Yet, at the eleventh hour, the award of this charter was suddenly withheld.

The reason for this was the intervention of the Universities of Oxford and Cambridge who, although not opposed to the granting of a charter *per se*, vigorously objected to the clause which would grant the power of conferring degrees to an institution of an avowedly irreligious nature. They were joined in this opposition by the London hospital schools, such as St. Bartholomew's, Guy's and St. Thomas's, who claimed equal rights to award such distinctions, taking exception to the proposal that medical students of this new establishment should be more privileged than those who attended their classes. With the combined weight of objections from these two major sources of opposition, plus the university's unwillingness to accept a compromise, the matter remained deadlocked for a further two years.²²³

By the summer of 1833, however, the university's claim for a charter had been reinforced by the previous year's recognition of the newly-erected University of Durham, so its campaign was once again re-launched. The key figure in the renewed agitation for full university status was William Tooke (1777-1863), one of the original council members who, as a newly-elected radical M.P. following the 1832 Reform Act, worked vigorously to promote the issue in Parliament. With the efforts of Tooke in the House of Commons and Brougham (who had been made a peer in 1830) in the Lords, Parliament was re-acquainted with the absurdity of a situation in which those who were not members of the Church of England, while theoretically politically enfranchised, could still not obtain English university degrees. In an attempt to eliminate this anomaly, the Commons passed the University Admissions Bill to allow Dissenters the right of graduation from Oxford and Cambridge,²²⁴ but it was rejected by the Lords. Consequently, the government was once again lobbied to return to the question of granting university status to an institution in London.

²²¹ Although these had merely granted them legal status, not the right to award degrees.

²²² *The Times*, 10 Feb. 1831, 4c.

²²³ *op. cit.*, (196), 14.

²²⁴ Bellot, *op. cit.*, (185), 239.

The problem was that London University was not the only candidate for this distinction - it was also claimed by King's College. Moreover, the petitions of the other medical schools to same rights as the university with regard to medical degrees also led to the recognition that, if the power to confer degrees were to be awarded to a body in the capital, it should be given to a far more wide-ranging and representative establishment than the existing London University. In July 1833, the *London Medical Gazette* made the following suggestion:

What is wanting to render London essentially an university, but to incorporate the several distinguished schools existing within it, thus rendering them virtually so many colleges, and to vest in a particular body the government of the whole? ... The particular body should not be part or parcel of any of the subordinate establishments; no teachers from the different schools, much less those of a particular school, should have any part in the control of the general institution.²²⁵

The university therefore realised that if it was to achieve the status it desired, it would have to make the further concession of waiving the right to award medical, as well as theological, degrees.²²⁶ This removed the hostility of the hospital schools, leaving only Oxford and Cambridge opposed. In March 1835, Tooke put forward a Commons motion that "an humble Address be presented to His Majesty, beseeching Him to grant His Royal Charter of Incorporation to the University of *London*, as approved in the year 1831 by the then Law Officers of the Crown, and containing no other restriction than against conferring degrees in divinity and in medicine".²²⁷ It was carried on the 26th by a majority of 110.²²⁸

In reply, the King assured the Commons that a charter would be granted, subject to a report from the Privy Council, yet when the charter finally appeared three months later, it took an unexpected form. On 17 July 1835, it was announced "that two Charters had been prepared, one in favour of the University of London in the precise form approved in 1831, but reducing its style to that of College, and thereby precluding its granting Degrees; and the other constituting a Metropolitan University, comprising a Board that should have power to examine for and confer Degrees on Students from the existing

²²⁵ *London Medical Gazette*, **12** (1833), 540.

²²⁶ *University of London. Statement of Facts as to Charter*, (London, 1835), 1.

²²⁷ *University of London. Report of the Council to the Proprietors. 25th February 1835*. (London: Richard Taylor, 1835), 14.

²²⁸ Bellot, *op. cit.*, (185), 242.

chartered Colleges in the Metropolis and its vicinity, and from such other Colleges as should hereafter be created by Royal Charter".²²⁹ While clearly not what Tooke and the other founders of the university had originally intended, this new proposal clearly added an extra dimension to the debate. Not only would it grant London University the recognition it sought, but also, by establishing a new independent degree-giving body, it would eliminate the rival claims of all the other London institutions to such a distinction. In short, the new plan was a very shrewd compromise.

Much discussion took place during the next few months on the merits of the proposed scheme, with a committee of the senate, consisting of Key, Malden and White, being appointed "to communicate with the council on the charter, & generally to take such steps as they may think necessary on the subject".²³⁰ Their report, which was published in the form of an address to the council, strongly recommended approval.²³¹ A special general meeting of proprietors was convened for 2 December, which, with an attendance of four hundred, unanimously passed the following resolution:

That His Majesty's Ministers, in consequence of the Address of the House of Commons of the 26th day of March last, and of His Majesty's most gracious Answer thereto, having devised a plan for conferring Academical Degrees more comprehensive and efficient than that contemplated by such Address, by extending to all other duly qualified Colleges for education equal facilities for obtaining Degrees, including those in Medicine, This Meeting, confiding in the sufficiency of the Board of Examiners to be constituted by the Government, and satisfied that this Institution has nothing to fear from competition with any other body, recommend to the Council gratefully to accept the Collegiate Charter offered.²³²

Following the council's endorsement of the resolution, matters returned to Parliament where the details of the two charters were finalised.²³³ Finally, on 28 November 1836, the great seal was affixed to the collegiate charter. With its acceptance by the proprietors two months later,²³⁴ confirmed on 8 April,²³⁵ the appellation of the body hitherto known

²²⁹ *op. cit.*, (226), 2.

²³⁰ UCC, No. 3495, Key, Malden and White to Council, 25 July [1835].

²³¹ *University of London. Address of the Senate to the Council on the proposed establishment of a Metropolitan University*, (London: John Taylor, 1835).

²³² *University of London. Special General Meeting of Proprietors. Held on Wednesday, the 2nd of December, 1835*. (London: Richard Taylor, 1835), 2-3.

²³³ *The Times*, 4 Sept. 1836, 2e.

²³⁴ *University College, London. Proceedings at the General Meeting of Proprietors, 22nd February, 1837*. (London: Richard Taylor, 1837), 5; *The Times*, 30 Jan. 1837, 6e.

as *London University* was altered to *University College, London*,²³⁶ although this was the only change effected to its constitution. On the same day, the issue of a second charter created a totally new organisation, the *University of London*,²³⁷ empowering it to examine and confer degrees in arts, law and medicine on students of University and King's Colleges who had completed prescribed courses of instruction.

Prospects for University College London now looked increasingly promising. Student class sizes were already beginning to rise by the end of 1836 - "That of Latin and Greek has this year advanced one fourth in each, and that of Mathematics one third"²³⁸ - and, with a restored public image and a high morale among its professoriate, there was every reason to hope that "when the opportunity of graduating in the Metropolis is afforded, many of the Classes may receive a very considerable increase".²³⁹ However, just as the college was about to enter its first session under its new name, an unexpected crisis arose in its department of mathematics.

3.3 De Morgan's Return

At the beginning of October 1836, only two weeks before the start of the academic year, the following letter was received by the council:

To the nearest relative of G. J. P. White M.A.

Sark. Sept 29th 1836

Sir

The painful task devolves upon me of informing you that Mr G. J. Pelly White M.A. Professor of Mathematics in the London University, Mrs G. J. P. White and Mrs White visited this island from Guernsey on Tuesday the 27 ult. and left it again on their return yesterday 28th at 11½ P.M. It blew very hard at the time and their boat which was very small and manned by two Guernsey Pilots was seen to fill in the midst of a raging

²³⁵ *University College, London. Proceedings at the Annual General Meeting of Proprietors, 28th February, 1838.* (London: Richard Taylor, 1838), 12.

²³⁶ The London University School similarly became University College School.

²³⁷ *The Times*, 13 Dec. 1836, 3c.

²³⁸ *op. cit.*, (234), 11.

²³⁹ *University of London. Annual General Meeting of Proprietors. Wednesday, 24th February, 1836,* (London: Richard Taylor, 1836), 7.

sea and the whole found a watery grave. The weather was too boisterous to render any assistance, though attempted, the calamitous accident happening about one mile from the shore. I am informed they were dissuaded from embarking in so small a boat but Mr W. determined on returning.

I have moreover to acquaint you that they lodged at Tozers Hotel Guernsey where they had left their luggage and which will be safely kept till an answer arrives. Should in the mean while the bodies of the unfortunate sufferers be found they will be decently interred in the church yard here. If I can be of any further assistance to the relatives under so afflictive a dispensation a letter addressed to me at Guernsey will be duly attended to.

I have the honor to be Sir
your most obedt Servt
P Le Pelley
Seigneur of Sark.²⁴⁰

This disaster could scarcely have happened at a worse time for the college. Whereas the loss of a professor in a minor subject, such as Spanish for example, would have caused no great inconvenience to the students, mathematics was crucial to the general college syllabus, not only in its own right, but as a vital preparation for natural philosophy. Furthermore, since the classes were due to reopen on 17 October, it would clearly be impossible to find a successor available to teach at such short notice. In view of this emergency, one of the professors seems to have taken matters into his own hands to simultaneously solve the problem by skilfully engineering the return of the first professor of mathematics to the institution. On 8 October, the council received a letter from Thomas Hewitt Key, informing them that he had met De Morgan the previous day to communicate the news of White's death. He reported:

While he [De Morgan] deeply feels the loss of one whom he much esteemed, he perceives likewise how much the interests of the general school are likely to suffer from that loss. Under this feeling he has authorized me to state that he will undertake the duties of the Mathematical Professorship until Christmas, by which means the council

²⁴⁰ UCC, No. 3748, Letter addressed: "H. Davis Esq. London University, if absent to the Head Master or any other resident member, *important to be opened immediately*", 29 Sept. 1836.

will have time for deliberately filling up the vacancy. I am sure that the Council and my colleagues will appreciate the kindness of this offer which I will add was perfectly spontaneous.²⁴¹

De Morgan's proposal was immediately accepted by the council with a special vote of thanks being passed "for the kindness and consideration with which he had come forward on the occasion".²⁴² In the mean time, they ordered "that it be announced in the usual public journals that the Professorship of Mathematics is vacant & that applications for the appointment would be received by the Council".²⁴³ The first and, it would appear, the only applicant for the vacancy was a young and rising Cambridge mathematician, Philip Kelland (1808-1879),²⁴⁴ the senior wrangler of 1834 who would, in 1838, become the first Englishman to be appointed professor of mathematics at Edinburgh University.²⁴⁵ Yet despite Kelland's evident suitability for the London chair and abundant promise of future eminence, by the time his application reached the council, it had been rendered redundant by further developments at the college.

Key had obviously been assiduous in his role as intermediary between De Morgan and the council since it would appear that, having secured De Morgan's return to his former position, he was also instrumental in ensuring that every effort was made to keep him there. According to the council minutes of 15 October, "Mr Key stated that it was much desired by himself and several of his colleagues with a view to promote the interests of the Faculty of Arts in this Institution, that a permanent arrangement for filling the Chair of Mathematics should be made without delay: it seemed to them advisable that the offer of the appointment should be made at once to Mr De Morgan, who, they had reason to believe, would accept it, if invited to do so, although for many reasons, it would not appear to him right, that he should be a Candidate..."²⁴⁶ On the basis of this information, a special council meeting was summoned two days later for the expressed purpose of re-appointing De Morgan to the chair of mathematics.

The intimation from Key that an offer would be made to restore him permanently to his former position, while certainly flattering, would also have been mildly embarrassing for De Morgan as it may have seemed somewhat hypocritical to accept precisely the same

²⁴¹ *ibid*, No. 3763, Thomas Hewitt Key to Charles C. Atkinson, 7 Oct. 1836.

²⁴² Council Minutes, vol. III, f.67.

²⁴³ *ibid*.

²⁴⁴ UCC, No. 3765, Philip Kelland to Thomas Coates, 8 Oct. [1836].

²⁴⁵ Venn, *op. cit.*, (26), 4, 9; *D.N.B.*, 30, 339-40.

²⁴⁶ Council Minutes, vol. III, f.68.

post in an institution he had recently left on (supposedly) strong principles. To ease his conscience, as well as to ensure that the college's amended constitution would obviate a recurrence of the events of 1831, he wrote a lengthy letter to his friend, the lawyer Sir Harris Nicolas, requesting advice on the propriety of his return. From this communication it is clear that, although he professed indifference as to whether the reply was favourable or not, he firmly intended to comply with his friend's recommendations.

What is equally obvious, however, is that he retained much fondness for the college and his previous position, an affection which clearly transcended all financial considerations. As he wrote, "Should I accept any offer (for I shall certainly not be a candidate) I should rather lose than gain for the time; and I do not consider the prospect of ultimate gain as greater than that I now have. The advantage would be the resumption of an occupation which is in itself pleasant to me, and which has some few pleasing associations."²⁴⁷ Sir Harris's reply has not been preserved but its content must have been positive, and, one would assume, to De Morgan's satisfaction, since he immediately authorised Key to accept any offer made by the council on his behalf.²⁴⁸

On Monday 17 October, the council met to decide on De Morgan's re-appointment. It will be recalled that, under the college's amended constitution, no professorial selection could be made without the consideration of a report from the senate on the matter. Needless to say however, since the proposal for De Morgan's reinstallation had originated from the senate, the professors' resolution was a model of approbation for their former colleague:

The Senate, from their experience of Mr De Morgan's success as a Professor, when he formerly held office in this Institution, and from his great reputation in the scientific world, are of opinion that the Council would not be able to find a more competent person to fill the vacant chair. As it will be of very great benefit to the University to fill the vacant professorship before the commencement of the Session, the Senate will place no difficulty in the way of Mr De Morgan's immediate appointment.²⁴⁹

²⁴⁷ S. E. De Morgan, *op. cit.*, (2), 73.

²⁴⁸ UCC, No. 3779, De Morgan to Charles C. Atkinson, 19 October 1836.

²⁴⁹ Council Minutes, vol. III, f.75.

Following this solid endorsement, "It was Resolved Unanimously That Mr De Morgan be appointed Professor of Mathematics."²⁵⁰ For the second time in his career, by what can only be described as tremendous good fortune, De Morgan had secured a much coveted academic appointment in an institution which, five years previously, he would never have considered re-entering. Yet, although fundamentally the same establishment, University College was very different, both in character and constitution, to the troubled London University which he had left in 1831. With its integrity fully restored and all objections regarding the credibility of its professors removed, De Morgan could accept this new appointment secure in the knowledge that his public reputation was unimpaired by so doing. It was thus, under these favourable conditions, that De Morgan once again entered into his professorial duties.

²⁵⁰ *ibid*, f.76.

Chapter 4

De Morgan and mathematical tuition at University College, 1836-1867

4.1 The new University

The next stage of De Morgan's career was to span an uninterrupted interval of over thirty years, a period which, unlike his first term in office, was comparatively calm and uneventful. This was true both within and without the walls of University College. Indeed, as the years progressed and the Gower Street institution became less of a novelty, what was once controversial gradually became the norm. This is reflected by the number of relevant articles in the press which, for this period, amounted to a fraction of those published in the previous decade. Yet while the new era was characterised by an diminution of the tumultuous events and controversies so prevalent in the college's formative years, it is also distinguished by an increase in the number of available sources pertaining to the teaching of mathematics and college life in general. Indeed, unlike the period discussed in the previous chapter, so plentiful is the relevant material that it will be advisable to divide the discussion into two sections.

Consequently, material concerning the experiences of De Morgan's students will form the basis of chapter 5, while this chapter will deal more directly with the mathematical instruction itself, comprising an analysis of De Morgan's tuition and its development during this extended period, together with the mathematical teaching of his various colleagues in the chair of natural philosophy. It should be stressed, however, that all teaching at the college was performed entirely independently of the new University of London, which, it will be recalled, had been created purely to examine students for academic degrees. Therefore, before we enter into such a discussion, it would be appropriate at this point to explain the system of examination adopted by the new body, preceded by some impression of De Morgan's views on what the fledgling University should aim to achieve.

4.1.1 De Morgan's suggestions

While there now existed a body fully entitled to bestow degrees in London, there were as yet no regulations or required courses of study for its prospective graduates to follow.

The task of drawing up such a document was given to the University's first senate, whose scientific contingent included Lord Brougham, George Airy, Michael Faraday, Richard Sheepshanks and John William Lubbock, the first Vice-Chancellor.¹ Such an assignment was clearly not to be undertaken lightly and took some considerable time to complete, during which there was much comment and speculation from many quarters as to what the University should aspire to become. Yet public opinion remained very much divided as to the propriety of such a body, an uneasiness compounded by its association with such a radical institution as University College. The following extract from *The Times* from February 1837 illustrates the antagonism which still existed to the new scheme, being a satirical selection of "Mathematical Questions for the University College, Gower-Street", which, while certainly humorous, were clearly motivated by political rather than academic considerations:

The kingdom of England is governed by Kings, Lords, and Commons; might not this be called the rule of three? What inconvenience would arise from leaving out the second? Show how small it would be.

Explain the difference between terms of an arithmetical series and terms of contempt, and prove that no number of the latter can have unity for the result.

Does not Professor Vaux² attach great importance to the mechanics? On what ground does the Professor's opinion rest?

Explain what is meant by variation. Give instances on Professor Vaux's system, and state why the Professor prefers the use of curved lines in all his operations.

What is the limit of Professor Lushington's³ theorem? Explain the chief difficulties in finding it, which have made some learned men think it has no limit at all. In proceeding according to this theorem, do you not often arrive at irrational results?

The earth revolves once in a year. Assuming such data as you know to be true, show when England will accomplish a revolution.⁴

¹ *The Times*, 13 Dec. 1836, 3c.

² Brougham's full title was Henry, 1st Lord of Brougham and Vaux.

³ Stephen Lushington (1782-1873), Whig MP and ardent reformer. One of the founders of both the original London University and the SDUK.

⁴ *The Times*, 7 Feb. 1837, 6d.

In the absence of any definite statement of intention on behalf of the senate during 1837, De Morgan took the opportunity to contribute to the debate on the scope of the new university, the forum for these opinions being an introductory lecture delivered at the opening of University College's faculty of arts for the new session in October of that year. Perhaps because he considered its topic of wider public interest than his inaugural lecture of nine years previously, De Morgan had this speech published as a small pamphlet, entitled *Thoughts suggested by the establishment of the University of London*. It displays the same overall ideas on the objectives of education as are contained in his initial lecture and other pedagogical writings; however, due to the nature of the subject under consideration, they necessarily cover a much wider field.

Alluding to the institution to which he had recently returned, he admitted "I am pleased to say this College, instead of this University. All my prepossessions point out an edifice devoted to instruction as a College, and define a University as a corporation, composed it may be of Colleges, but existing independently of them."⁵ Perhaps because of its passing resemblance to the collegiate structure at Oxford and Cambridge, De Morgan appears to have heartily approved of the new arrangement - indeed, on these very grounds, he would have strongly objected to today's University of London, which has teaching as well as examining responsibilities. As he later declared in a letter to Lubbock, "it is one of the most valuable parts of our Cambridge system, that the *University* does not prescribe or interfere with details of College instruction, but only tests the results".⁶

Although, as shall be seen, he could be sharply critical of the established English universities and often drew attention to their flaws, he strongly urged that the new university should seek to emulate the strengths of the older institutions and use them to its own advantage. Indeed, he was equally quick to criticise those who believed that the established systems were defective almost by definition: "Among those who do not know the Universities, there frequently exists something which resembles the opinion, that the more unlike any system to those pursued at Oxford and Cambridge, the better it is likely to be."⁷ This, he argued, was an unwise position to hold, since those who concentrated on the defects of the university system frequently overlooked the advantages.

⁵ Augustus De Morgan, *Thoughts suggested by the establishment of the University of London: An introductory lecture, delivered at the opening of the Faculty of Arts, in University College, Oct. 16, 1837*, (London: Taylor and Walton, 1837), 28.

⁶ Printed letter from Augustus De Morgan to John William Lubbock, 4 Dec. 1838, in book of bound pamphlets, University of London Library, shelf mark: [QML Additions] 370 (B.P.1), 73-74.

⁷ *op. cit.*, (5), 5.

Of the deficiencies (which, he acknowledged, were many), it is not surprising that he chose to highlight the one which not only caused the premature end to his career at Cambridge but also led to the founding of both University College and the University of London. Yet, while he admitted that it was impossible for him "either to excuse or palliate that unfortunate principle upon which they have separated themselves from the nation at large, and declared themselves to be the nursing mothers of those only who profess to hold one form of religious faith",⁸ he averred that, with this one qualification, there was much in the systems of Oxford and Cambridge from which the University of London could learn. Indeed, referring especially to "the University in which I received my own education," he asserted that "years of study and reflection have convinced me that I am indebted to an extent of which I little knew when I left its walls".⁹

His principal defence of the older establishments came from his belief in the discipline their adopted courses of study instilled in the mind, resulting from being principally confined to Latin, Greek and, at Cambridge, mathematics. He defended this narrow range of subjects against the wider syllabus proposed for the new university from the conviction that concentration on one particular academic field was vital to a complete university education. He believed that at least one subject should be studied in very great depth, to give the student an idea of how far knowledge in that area extended. To him, the choice of the subject was relatively unimportant; what mattered was that the student should learn to appreciate the scope of human knowledge by the means of a chosen example. As he said:

There is in every branch of knowledge a beginning, a middle, and an end: a beginning, in which the student is striving with new and perhaps difficult principles, and in which he is relying in a great measure on the authority of his instructor; a middle, in which he has gained some confidence in his own knowledge, and some power of applying his first principles... Let him only proceed, and he will come to what I have called the end of the subject, and will begin to see that there is, if not a boundary, yet the commencement of a region which has not been tracked and surveyed, and in which not all the skill which he has acquired in voyaging by the chart will save him from losing his way. It is at this period of his career that he will begin to form a true opinion of his own mind, which, I fully believe, is not done by many persons, simply because they have never been allowed

⁸ *ibid.*

⁹ *ibid.*, 30.

to pursue any branch of inquiry to the extent which is necessary to shew them where their power ends.¹⁰

De Morgan argued that the scheme of instruction at Oxford and Cambridge promoted this way of studying, as opposed to the proposed system which, he claimed, would merely give the student a superficial acquaintance with a wider range of subjects. This, he believed, would not indoctrinate the student with the reasoning power he prized so highly: "To make a subject teach the mind how to inquire," he said, "it must be carried beyond the point at which the necessity for inquiry commences."¹¹ For this reason in particular, he formed his opinion "that the ancient universities, in laying down, as it were, few and distinct objects of study, did not pursue a course for which they deserve to be the objects of censure."¹²

He offered an explanation for the perceived need for an alternative mode of instruction, drawing attention to a misconception that the study of classics and mathematics at school rendered their further consideration superfluous:

"My son," says a parent, "has been at college for four years, and they taught him nothing but Latin, Greek and mathematics, which he knew when he left school." Now, let us think for a moment what this may mean? The boy, when he left school, may have construed Cicero and Herodotus, read four books of Euclid, and been master of decimal fractions and equations.... The young man, when he leaves college, may have read all the most useful Latin writers,... blending his reading with the best modern dissertations on the subjects treated by the ancient writers.... He may have studied the models which the Greeks have left us in every branch of literature, and entered largely into the historical connexion between them and ourselves. He may have attended closely to mathematical analysis, and have traced by its means the connexion of the great bodies of our universe, the laws of matter, of light, of heat, of electricity... [E]ven on the supposition that a young man has schooled himself by every method of deduction and induction, and has exercised his tastes and faculties by the study of history, criticism, controversy, eloquence, satire, and poetry, there are parents who would be able to see nothing more in all this than reason for desiring a reform in education, *because* - their sons learn nothing but Latin, Greek, and mathematics.¹³

¹⁰ *ibid*, 7-8.

¹¹ *ibid*, 10.

¹² *ibid*, 11.

¹³ *ibid*, 13.

While he was far from suggesting that these subjects should be scrutinised to the exclusion of all else, he saw much danger in promoting a widely extended system of study: "A small quantity of learning quickly evaporates from a mind which never held any learning except in small quantities... Even if he can be said to have varied learning, it will not long be true of him, for nothing flies so quickly as half digested knowledge".¹⁴ Moreover, as he later put it, "the habits produced by such acquisition are of inferior soundness, and less utility".¹⁵ For this reason, he maintained that, in order to attain a University of London degree, it should not be sufficient for students merely to study a wide range of topics at a superficial level, but that "*depth of knowledge* in certain subjects ought to be made the requisite of a university distinction".¹⁶

In order to achieve this goal, De Morgan highlighted two procedures whereby knowledge was usually acquired: "The first is by diligent study in the retirement of the closet; the second, by haunting the benches of the lecture-room, and picking up what may chance to fall."¹⁷ Not surprisingly, considering his own voracious appetite for private study, of the two methods he deemed the former to be by far the more effective, considering the role of lectures as merely providing students with hints on what to read and assistance in resolving difficulties. In defence of the Oxford and Cambridge systems, he argued that "whatever their defects may be, and they are not small, their system has made diligent private study a great many times more essential to the attainment of distinction than attendance upon lectures".¹⁸ This, in De Morgan's view, was the most praiseworthy feature of the English university system.

By this rationale, he considered that if future graduates of the University of London achieved distinction largely through a wide and thorough course of reading, the new system could be deemed to be working effectively. "But," he said, "if I find the future graduates doing little or nothing more than attending their professors - if I discover that they consider the lectures as the most prominent and important means of obtaining what they seek - I shall feel assured that the time for competing with the ancient universities will not arrive in our day."¹⁹ Lectures alone, he maintained, were insufficient to fully

¹⁴ *ibid*, 12.

¹⁵ Augustus De Morgan, On the effects of competitory examinations, employed as instruments in education, *The Educational Times*, 1 Dec. 1848, 56-59, 57c.

¹⁶ *op. cit.*, (5), 13.

¹⁷ *ibid*, 14.

¹⁸ *ibid*, 15.

¹⁹ *ibid*.

instruct a student to the level he believed necessary for distinction at degree level, encouraging laziness and dependence on the lecturer. Moreover, the notes taken by students at lectures, while important, were no substitute for a full treatise; indeed, he compared the information obtained from listening to a lecture to the comprehension achieved from reading a book at speed.

Another reason for De Morgan's belief in the necessity for the new university to ally itself with the established system was that its degrees were to bear the same titles as those bestowed by Oxford and Cambridge. In other words, De Morgan expressed concern that a B.A. graduate from the University of London might be considered as having gone through the full classical and mathematical syllabus when in fact he had chosen to read just one isolated subject, such as natural history. This, he argued, would amount to defrauding the public: "Long established usage has told the whole community that the honours of the ancient universities are significative of distinction in classics, or mathematics, or both: but the rising institution, which has the character of being founded upon an independent basis, cannot, it appears to me, either in honesty or policy, allow a general term to stand for essentially different species of education."²⁰

The solution he favoured was that of requiring that the student should sit an initial examination in classics, elementary mathematics and possibly a modern language in order to demonstrate a moderate degree of proficiency, and then allowing a free choice of subsequent study on which basis he would obtain his final degree. This scheme appealed to De Morgan since "on the one hand, it secures a moderate degree of attention to those points on which ignorance would be absolute disgrace, while, at the same time, it throws the student upon diligent and accurate subsequent study".²¹ The main drawback to this idea was that, since it was expected that "the students who seek degrees in the University of London will be younger than those who go to Oxford or Cambridge, by perhaps a couple of years",²² it was only to be expected that youths of sixteen and seventeen would choose the subjects they enjoyed rather than those from which they would derive the most benefit.

Of all the issues surrounding the new university, that which De Morgan considered the most problematic was the question of whether its degree should be a mark of ordinary

²⁰ *ibid*, 21.

²¹ *ibid*, 22.

²² *ibid*.

attainment or distinction. At Oxford and Cambridge, the award of a degree merely signified recognition of a certain standard of achievement, whereas the same with honours was regarded as a distinction. To De Morgan, it was essential that the University of London should clarify this difference with respect to the awards it proposed to offer. "What," he asked, "will be the value of its distinctions? With what degree of intensity will they be sought? On the answers to these questions depends that of the following:- How much may be required of those who desire a degree?"²³ He, of course, could not answer this question; such a specification could only be provided by the senate.

Compared to his liberal views on how education should be administered, as revealed in his inaugural lecture and writings for the SDUK, De Morgan's opinions on how university education should be structured seem somewhat conservative. Obviously the former were the result of an acquaintance with the progressive work of continental teachers, whereas the latter clearly reveals the influence of his study at Cambridge. But this is not to say that his conception of what the University of London should expect of its graduates was retrogressive. Indeed he emphasised the need to combine the most agreeable features of the older universities with more innovative arrangements to produce a new system equally entitled to the name of university. Yet with the circulation of so many divergent ideas and suggestions on what the university should aim to achieve, it was inevitable that De Morgan's suggestions could not all be incorporated into the scheme which eventually appeared.

4.1.2 The University Syllabus

Regulations for University of London degrees in arts were finally published by the senate in 1838. These established three main levels of examination for students at the university's associated colleges. The first was matriculation, designed to be taken at the commencement of the student's college studies. This was to take place in the first week in October of every year, being open to students of sixteen and over. A fee of £2 was payable for admittance to the examination, although if a student failed, he would have his fee returned in full.²⁴ The subjects under examination were mathematics, natural philosophy, chemistry, natural history (i.e. botany and zoology), Latin and Greek, English

²³ *ibid*, 27.

²⁴ *University College, London. Proceedings at the Annual General Meeting of Proprietors, 27th February 1839*, (London: Richard and John E. Taylor, 1839), Appendix I: *University of London. Regulations for Examinations for Degrees*, 20.

language, and rudimentary history and geography. The full requirements for mathematics and physics were as follows:-

MATHEMATICS

ARITHMETIC AND ALGEBRA:

- The ordinary rules of Arithmetic.
- Vulgar and decimal fractions.
- Extraction of the Square Root.
- Addition, Subtraction, Multiplication, and Division of Algebraical Quantities.
- Proportion.
- Arithmetical and Geometrical Progression.
- Simple Equations.

GEOMETRY:

- The First Book of Euclid.

NATURAL PHILOSOPHY

MECHANICS:

- Explain the Composition and Resolution of Statical Forces.
- Describe the Simple Machines (*Mechanical Powers*), and state the Ratio of the Power to the Weight in each.
- Define the centre of Gravity.
- Give the General Laws of Motion, and describe the chief experiments by which they may be illustrated.
- State the Law of the motion of falling bodies.

HYDROSTATICS, HYDRAULICS, AND PNEUMATICS:

- Explain the Pressure of Liquids and Gases, its equal diffusion, and variation with the depth.
- Define Specific Gravity, and show how the specific gravity of bodies may be ascertained.
- Describe and explain the Barometer, the Siphon, the Common Pump and Forcing-Pump, and the Air-Pump.

ACOUSTICS:

- Describe the nature of Sound.

OPTICS:

- State the Laws of Reflection and Refraction.
- Explain the formation of Images by Simple Lenses.²⁵

The results of this examination would be published one week later, when successful candidates (under the age of nineteen) were entitled to matriculate for honours in mathematics and natural philosophy and/or classics. Mathematical requirements for this

²⁵ *ibid*, 20-21.

series of examinations amounted to a knowledge of the above with the addition of conic sections and plane and spherical trigonometry.²⁶ Those who achieved the best examination results in the mathematical and classical papers would each receive a scholarship of £30 per annum for two years' further study at either of the two London colleges.²⁷ Examiners in the various subjects were appointed by the senate for a period of one year beginning in June or July.²⁸ For the university's first matriculation examinations in October 1838, the mathematical examiners were the Revs. George B. Jerrard and Robert Murphy.²⁹

After matriculation, the second category of examination was that for the degree of Bachelor of Arts, the first of which was held on 27 May 1839, extending for a period of one week. This was to be taken within two academic years of the student's successful matriculation. In addition to this, in order to be eligible for this examination, the student had to present certificates from his college to show that he had followed its prescribed course of study for two years and that his conduct had been satisfactory during that time. The fee for entrance to this examination was £10, although, again, it was returnable if the candidate was unsuccessful.³⁰ As well as mathematics and natural philosophy, candidates for the new B.A. degree could also expect to be examined in Latin, Greek, chemistry, animal physiology, vegetable physiology and structural botany, and logic and moral philosophy - with optional papers in history, French and German. In the mathematical sciences, the following knowledge was required:-

MATHEMATICS AND NATURAL PHILOSOPHY

ARITHMETIC AND ALGEBRA:

- The ordinary rules of Arithmetic.
- Vulgar and Decimal Fractions.
- Extraction of the Square Root.
- Addition, Subtraction, Multiplication, and Division of Algebraical Quantities.
- Algebraical Proportion and Variation.
- Permutations and Combinations.
- Arithmetical and Geometrical Progression.
- Simple and Compound Interest; Discount, and Annuities for terms of years.

²⁶ *ibid*, 23.

²⁷ *ibid*, 24.

²⁸ *ibid*, 33.

²⁹ *ibid*, 38. Robert Murphy (1806-1843) was an Irish-born mathematician (and 3rd wrangler in 1829) who, according to De Morgan, "had a true genius for mathematical invention ...[and whose] works on the theory of equations and on electricity, and his papers in the *Cambridge Transactions*, are all of high genius". - *D.N.B.*, 39, 343.

³⁰ *ibid*, 25.

Simple and Quadratic Equations, and Questions producing them.
The nature and use of Logarithms.

GEOMETRY:

The First Six Books of Euclid.
The principal properties of triangles, squares, and parallelograms, treated geometrically.
The principal properties of the circle treated geometrically.
The relations of similar figures.
The Eleventh Book of Euclid to Prop.21.
The equation to the straight line, and the equation to the circle referred to rectangular co-ordinates.
The equations of the Conic Sections referred to rectangular co-ordinates.

PLANE TRIGONOMETRY:

Plane Trigonometry as far as to enable the Candidate to solve all the cases of Plane Triangles.

The following propositions: $\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B$
 $\cos (A \pm B) = \cos A \cos B \mp \sin A \sin B$
 $\tan (A \pm B) = \frac{\tan A \pm \tan B}{1 \pm \tan A \tan B}$

The expression for the area of a triangle in terms of its sides.

MECHANICS:

The composition and Resolution of Forces.
The Mechanical Powers.
The centre of Gravity.
The general laws of Motion.
The motion of falling bodies in free space and down inclined planes.

HYDROSTATICS, HYDRAULICS, AND PNEUMATICS:

The pressure of fluids is equally diffused and varies as the depth.
The surface of a fluid at rest is horizontal.
Specific gravity.
A floating body displaces exactly its weight of fluid, and is supported as if by a force equal to its weight pressing upwards at the centre of gravity of the displaced fluid.
The Common Pump and the Forcing Pump.
The Barometer.
The Air Pump.
The Steam Engine.

ASTRONOMY:

The apparent motion of the heavens round the earth.
The apparent motion of the sun through the fixed stars.
The phenomena of eclipses.
The regression of the planets.
Proofs of the Copernican system.³¹

³¹ *ibid*, 25-26.

Mathematical and classical honours were also available for successful degree candidates aged less than 22. These would take place in the week immediately following the B.A. examinations, i.e. during the first or second week of June. For these, the mathematical prerequisites were substantially higher than before, with students requiring a knowledge of algebra up to the theory of equations, analytical geometry, differential and integral calculus, probability theory and the calculus of finite differences.³² As with the matriculation examination, the most outstanding honours graduates in both classics and mathematics would be awarded a prize, in this case receiving the title of University Scholar together with £50 per annum for three years.³³

At the same time of year as the bachelors' examinations, those for the Master of Arts degree would also be held. These were open to university graduates of at least one year's standing, provided they were over the age of twenty. Examinees could choose to be examined in one or more of three categories: mathematics and natural philosophy; classics; and logic, moral philosophy, philosophy of the mind, political philosophy and political economy.³⁴ For the first category, the mathematical part of the syllabus was the same as for the honours examination, while the physical section was extended to include heat, electricity and magnetism, optics, and plane and physical astronomy. Those who achieved the highest distinction in each category would be awarded a gold medal worth £20.³⁵

In June 1839, the University of London awarded its first degrees, conferring the title of Bachelor of Arts on seventeen candidates, who were divided by the examiners into two classes of merit. Of these seventeen graduates, thirteen were University College students, of whom eleven out of twelve were placed in the first class, while two out of five were in the second.³⁶ The only honours graduate in mathematics that year (indeed the only candidate to submit to such examination) was De Morgan's outstanding pupil Jacob Waley, to whom we referred briefly in section 3.1 and will meet again in the following chapter. Waley also headed the list of the five honours graduates in classics, receiving the first university scholarship of £50.³⁷

³² *ibid*, 30.

³³ *ibid*, 32.

³⁴ *ibid*.

³⁵ *ibid*, 33.

³⁶ *University College, London. Proceedings at the Annual General Meeting of Proprietors, 26th February, 1840*, (London: Richard and John E. Taylor, 1840), 5.

³⁷ *ibid*, 6.

This system of examinations remained in effect for twenty years until 1858, when a new charter was conferred on the university, altering its constitution in several key areas. Most notably, it established the new degrees of Bachelor and Doctor of Science to distinguish those whose education had concentrated more on scientific subjects,³⁸ although the council of University College strongly urged their students not "to underrate the advantage of a full education for a Degree in Arts, or to content themselves with scientific without literary education, or with literary without scientific education".³⁹ More controversially, the new charter removed the original restriction that, in order to graduate, a student must have completed a course of study at one of the affiliated colleges.⁴⁰ Now, irrespective of educational background or qualifications, anyone, on payment of the requisite fee, could try for a University of London degree. For this reason, "the new constitution was regarded by the majority of the college with profound disapproval",⁴¹ one particularly vocal critic of both the original and the amended systems being Augustus De Morgan.

4.1.3 De Morgan's criticisms

According to his biographer, De Morgan "strongly expressed his disapproval of the course proposed by the University of London on its first establishment",⁴² although the severity of his comments appears to have increased with time. That said, however, his criticisms were evident from the outset, the earliest being contained in a letter to John Lubbock from December 1838, where he expressed misgivings about the formidable requirements for the university's matriculation examination. In his opinion, "the Matriculation Examination in Arts, as it already exists, is quite difficult enough, and probably a little too difficult".⁴³ He continued, "I should hope that in time the standard might be raised; but I am strongly in favour of setting off from a point not very far from that at which the world in general stands at the outset."⁴⁴

³⁸ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1859*, (London: Taylor and Francis, 1859), 12.

³⁹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 29th February, 1860*, (London: Taylor and Francis, 1860), 10.

⁴⁰ *op. cit.*, (38), 11.

⁴¹ Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 303.

⁴² Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, and Co., 1882), 183.

⁴³ *op. cit.*, (6), 73.

⁴⁴ *ibid.*

The bulk of his objections are contained in a lengthy letter to Michael Foster, University College's professor of physiology, written in 1853. One important reason for his opposition to the system adopted by the university was what he deemed the fruitless waste of mental effort, largely resulting from the "enormous variety of subjects on which a young man was required to answer questions, without reference to any special ability".⁴⁵ In the letter, he focused his criticisms on the B.A. examination, drawing attention to the need for candidates, "in addition to matters which enter the ancient disciplines, to be examined in *animal physiology*", particularly when "a large majority of those who have passed the examination in physiology know nothing about the interior of the body from their own observation except that blood follows a cut in the finger".⁴⁶ He complained that to pass the physiology examination, the students needed only to learn words to describe objects which they had never observed.

As De Morgan saw it, one of the new university's unique tasks was to accord the status of discipline to branches of knowledge which were unrecognised by the older establishments. A key point which he believed the new system could teach the old was "the neglect of the discipline of observation, of language as connected with it, and of inference as immediately derived from it". Yet, he complained, the university's syllabus entirely failed to capitalise on this opportunity:

And how has the University of London fulfilled its especial mission? It has granted the existence of the deficiency, proclaimed its own intention to provide a remedy, and set its alumni diligently to work to read words and to look at diagrams about the way in which other people have used their eyes and their hands.⁴⁷

Naturally, he also had plenty to say regarding mathematics, his comments on the university's requirements in this area being particularly critical. According to his wife, so strong were his objections to the university's system that he "refused to take part in the examinations".⁴⁸ However, since the university was explicitly excluded from all teaching responsibilities, it seems very unlikely that he would ever have been called upon to do so. Being a professor at one of the university's affiliated colleges, De Morgan would certainly not have been deemed sufficiently impartial to be appointed one of its mathematical examiners. In any case, his comments reveal that he considered the system to be far from

⁴⁵ S. E. De Morgan, *op. cit.*, (42), 183.

⁴⁶ *ibid.*

⁴⁷ *ibid.*, 224.

⁴⁸ *ibid.*, 183.

perfect, one particular criticism being that, in the list of mathematical propositions required for the degree examination, the implication is conveyed that the examiners had no regard or preference for how the material should be acquired.

We are informed that the principal properties of triangles, squares, and parallelograms (when did the square cease to be a parallelogram?) are to be treated geometrically. Among the principal properties of parallelograms are those of similar parallelograms; their study involves a doctrine of proportion. But only the first of the six books of Euclid are demanded. Must similar parallelograms be treated by what is called a geometrical theory of proportion? If not, how are the principal properties of parallelograms to be treated *geometrically*, as demanded? If yes, what is that geometrical theory of proportion, other than Euclid's, so well known that it may be trusted to implication? The only proportion alluded to in any part of the list is *algebraical* proportion, which, as usually understood, is the doctrine of the ratios of commensurable quantities, expressed by letters, with either every possible amount of gratuitous assumption about incommensurable quantities, or else a total refusal to consider them.⁴⁹

Yet, while De Morgan had much to say on the matter of requirements for certain branches of knowledge, the content of the University of London syllabus was not the focus of his principal and most vehement criticisms - it was the system employed for the examination of students. Due perhaps to his own experiences at university, De Morgan had very strong opinions on student assessment and testing. While firmly agreeing with the need for examinations, he was severely critical of their competitive nature, believing competition to be worthless as a system either for producing or revealing the best scholar; he always refused to examine papers by allocating marks, preferring to judge the merit of the work as a whole rather than individual components. To those who asked what would be the stimulus if competition were removed, his reply was simple: "No stimulus is needed beyond their own pleasure in learning; and if a teacher cannot make them feel this, he does not deserve the name of teacher."⁵⁰

The fundamental flaw in the plan of the University of London, in De Morgan's eyes, was the emphasis it placed on competitive examinations, and the effect thus produced on the studying habits of the student. He warned that, "A student whose thoughts dwell upon his examinations only, and who reads for them as for an ultimate end - thinking of processes as to how far they will help him in answering the questions asked - and of results as to

⁴⁹ *ibid*, 227.

⁵⁰ *ibid*, 170.

what their chance is of being in the printed papers - does not take a good mode of fixing anything in the mind for future use."⁵¹ This, he said, defeated the whole object of education, which he defined as "the attainment of *permanently* good habits, *permanently* strengthened powers, and accurate information, to be *permanently* fixed in the mind".⁵²

These habits and reasoning powers were, to De Morgan, worth more than all the knowledge that could be obtained in a university career, a view which he insisted was not unique to himself:

Let it be supposed that the former student has forgotten everything, that not a word of Latin is left, and not a proposition of Euclid. What remains to him? If little or nothing, then his education has not deserved its name. But if, in spite of the loss of all that acquirement which he has had no daily need to recall, he be a man of trained mind, able to apply vigorously, to think justly, to doubt discreetly, and to decide wisely, he has been well educated, and the loss of the positive knowledge which I suppose him to have lost is comparatively a small matter. I do not underrate knowledge; I would educate for it, even if it gave no powers; but I am sure that if we take care of the habits, the acquirements will take care of themselves.⁵³

Yet, he argued, the current system of examinations employed not only in the University of London, but elsewhere, including University College and the University of Cambridge, did nothing to encourage the development of these habits of mind. Indeed, he argued, they instilled the necessity for the student to 'cram' knowledge by means of hasty and unsystematic revision. Consequently, a candidate for such an examination "employs himself in collecting, without an attempt to digest. He puts by his unfinished and half-learnt material, to await the time when the examination is close at hand. Then, in the few days or weeks which precede the trial, he makes a rush at his crude mass of ill-understood notes, and endeavours to charge his unfortunate memory with the whole of it. There is no time to think of a process, to disentangle a confusion, or to give invention a fair chance of suggesting something for future consideration. All that is wanted is, to show a mass of learning on the day of examination, to make one successful effort during a few hours."⁵⁴

⁵¹ Augustus De Morgan, On the effects of competitory examinations, employed as instruments in education, *The Educational Times*, 1 Dec. 1848, 56-59, 57c.

⁵² *ibid*, 57b.

⁵³ S. E. De Morgan, *op. cit.*, (42), 226-7.

⁵⁴ A. De Morgan, *op. cit.*, (51), 57c-58a.

Contrasting the system of examinations practised at London and Cambridge, in which the candidate was examined against his competitors, with the Oxford practice, as he saw it, of examining the student against his subject, he wrote:

The Oxford system has a tendency to develop the useful differences between the varied types of human character. The Cambridge system is an unconscious effort to destroy them. I shall not be suspected of any original bias against the Cambridge system. I once thought that the race for the place in the list was a valuable part of that system, but I have slowly arrived at the full conviction that the Oxford plan is greatly superior. The system of private tutors, the drill in *writing out*, and the mode in which so many of the elementary books are *got up*, are well worthy the attention of all who are interested in the subject of this letter. They are the natural consequences of the personal competition for honours; and if ever the number of candidates in the University of London should bear any considerable proportion to that in the University of Cambridge, the same cause will produce the same effect.⁵⁵

The content and structure of the Cambridge Tripos also met with his stern disapproval, being in his opinion "nothing but a hard trial of what we must call problems - since they call them so".⁵⁶ It was this emphasis on problem solving that De Morgan regarded as a fundamental weakness of the Cambridge examination system, since this practice, in his opinion, did not adequately encourage a thorough knowledge of the subject:

The whole object seems to be to produce problems, or, as I should prefer to call them, hard ten minute conundrums. These problems, as they are called, are, and are necessarily obliged to be, things of ten minutes or a quarter of an hour. It is impossible in such an examination to propose a matter that would take a competent mathematician two or three hours to solve, and for the consideration of which it would be necessary for him to draw his materials from different quarters, and see how he can put together his previous knowledge, so as to bring it to bear most effectually on this particular subject.⁵⁷

Examination questions, he believed, should be tailored to elicit the thought and mental power of the student rather than to show off the examiner's personal ingenuity. To illustrate the flaws of the systems employed at both the Universities of London and

⁵⁵ S. E. De Morgan, *op. cit.*, (42), 226.

⁵⁶ Augustus De Morgan, Speech of Professor De Morgan, President, At the First Meeting of the Society, January 16th, 1865, *Proceedings of the London Mathematical Society*, (1) 1 (1865-66), 1-9, p.3.

⁵⁷ *ibid*, 4.

Cambridge, he drew up a mock Cambridge-style examination paper, in reference to what he deemed the futility of both setting and sitting such papers:

- Q. What is knowledge?
A. A thing to be examined in.
Q. What is the instrument of knowledge?
A. A good grinding tutor.
Q. What is the end of knowledge?
A. A place in the civil service, the army, the navy, &c. (as the case may be).
Q. What must those do who would show knowledge?
A. Get up subjects and write them out.
Q. What is getting up a subject?
A. Learning to write it out.
Q. What is writing out a subject?
A. Showing that you have got it up.⁵⁸

De Morgan was convinced that "the effects of making all reward depend upon the results of one grand disgorgement are of an evil very much exceeding the good. I believe that it saves much trouble to teachers, at the expense of the learners."⁵⁹ He thus did everything in his power to avoid putting undue pressure on his students by encouraging the development of real understanding as opposed to cramming knowledge. His advice to students at the start of their college career was: "Take care of everything except the examination, and leave the examination to take care of itself",⁶⁰ and, as one ex-student later recalled, he certainly practised what he preached:

The claims which University or College examinations might be supposed to have on the studies of his pupils were never allowed to influence his programme in the slightest degree. He laboured to form sound scientific Mathematicians, and, if he succeeded in this, cared little whether his pupils could reproduce more or less of their knowledge on paper in a given time. On one occasion when I had expressed regret that a most distinguished student of his had been beaten, in the Cambridge Mathematical Tripos, by several men believed to be his inferiors, De Morgan quietly remarked that he "never thought ----- likely to do himself justice in THE GREAT WRITING RACE." All cram he held in the most sovereign contempt. I remember, during the last week of his course which preceded an annual

⁵⁸ S. E. De Morgan, *op. cit.*, (42), 184.

⁵⁹ University of London Library, MS. 775/328/1, f.8.

⁶⁰ A. De Morgan, *op. cit.*, (51), 59a.

College examination, his abruptly addressing his class as follows: "I notice that many of you have left off working my examples this week. I know perfectly well what you are doing; YOU ARE CRAMMING FOR THE EXAMINATION. But I will set you such a paper as shall make ALL YOUR CRAM of no use."⁶¹

To the present-day reader, the cause of De Morgan's observations should appear very familiar, since exam-oriented study, crammed revision and the dependence on results of fellow competitors for one's eventual grade are still prominent features in most current systems of university and college examinations. That so little has changed after well over a century would have been a great disappointment to De Morgan, particularly in view of the positive responses he received to his remarks from some contemporary quarters, including William Whewell at Cambridge and Baden Powell, the Savilian Professor of Geometry at Oxford. Yet both wanted to know what would best replace the system of competitive examinations, Baden Powell suggesting oral examination on dissertations written by the students.

However, for the most part, De Morgan's arguments received very little, if any, attention at the time, and although by 1882, his widow was writing that "wiser notions are coming into men's minds, and the evil is acknowledged,"⁶² she had to admit that, despite a fervent wish to do otherwise, she could not say that any changes had occurred in the way examinations were conducted at Oxford, Cambridge or London. De Morgan's hope for a better method of rewarding progress remained unfulfilled, despite the following optimistic prediction, made towards the end of his life: "There is much truth in the assertion that new knowledge hooks on easily to a little of the old, thoroughly mastered. The day is coming when it will be found out that crammed erudition, got up for examinations, does not cast out any hooks for more."⁶³

4.2 Mathematics at UCL

4.2.1 De Morgan's mathematical tracts

We have now examined De Morgan's opinions on how his students should (or rather should not) be examined. In the previous chapter, we also saw his views on how

⁶¹ Bellot, *op. cit.*, (41), 82.

⁶² S. E. De Morgan, *op. cit.*, (42), 171.

⁶³ Augustus De Morgan, *A Budget of Paradoxes*, (London: Longmans, Green, and Co., 1872), 167.

mathematical instruction should be administered. In this section, we will examine precisely what mathematics De Morgan taught during the major part of his duration at University College. This time, unlike his teaching of 1828-31 or the syllabus of George White which followed, our knowledge of De Morgan's course of instruction is far more complete. The reason for this is the existence of "a large mass of mathematical tracts which he prepared for the use of his students, treating all parts of mathematical science, and embodying some of the matter of his lectures".⁶⁴ These are preserved in the University of London Library in the form of more than 320 notebooks containing the majority of De Morgan's course material from this time in his own handwriting. By exploiting the contents of these valuable manuscripts, we can thus be far more explicit about the material he covered during this period.

As he had made clear in his introductory lecture of 1837, De Morgan regarded the role of lectures as merely providing students with assistance in difficulty and guidance on relevant reading. In order to enlarge on this oral instruction, he prepared a vast quantity of handwritten tracts on all aspects of his course which were then placed in the University College library for his students to refer to. They were designed to supplement not only the lecture material, but also the wide reading which De Morgan expected his students to undertake to broaden their mathematical erudition. Many would copy the contents of these tracts wholesale, as evinced by a large volume presented to University College containing a transcription of the first 33 tracts by one John Power Hicks.⁶⁵ On inspection, they read very much like manuscript versions of his textbooks, which is hardly surprising, since many of these probably started life in such form. Indeed, Hicks' notes reveal that the tracts numbered 1 and 2 "containing the Double Algebra were withdrawn on the publication of De Morgan's book".⁶⁶

Most of the notebooks are numbered, with tracts 1 to 175 and 186 surviving, although tract 101 is missing. Many tracts are divided into several parts so, for example, tract 96 is

⁶⁴ William Stanley Jevons, De Morgan, *Encyclopædia Britannica*, 11th edition, (Cambridge: Cambridge University Press, 1910), 8, 8-10, p.9.

⁶⁵ This student attended De Morgan's lectures between 1849 and 1851, before matriculating at Pembroke College, Oxford, in December 1851. Moving to Lincoln College the following year, he graduated B.A. in 1855. He later went on to become a barrister. - Joseph Foster, *Alumni Oxonienses 1715-1886*, 2, (London: Joseph Foster, 1888), 656.

⁶⁶ University College London Archives, MS.ADD.6, "Mathematical Tracts by Professor De Morgan, copied from the original Manuscripts in the Library of University College London by John Power Hicks 1849-1851", contents page. The book in question was De Morgan's *Trigonometry and Double Algebra*, (London: Taylor, Walton & Maberly, 1849).

composed of two notebooks; the first, numbered 96₁, has on its front cover "(Higher Senior) On Double Integration, February 25, 1851",⁶⁷ while on the second, 96₂, is written "(Higher Senior) Application to Solids and Surfaces (Double Integration) March 20, 1857".⁶⁸ Not all of the notebooks are dated but, of those that are, the earliest comes from 1843 and the latest from 1866. Throughout this time, De Morgan seems to have been constantly updating and rewriting these texts to improve both their overall intelligibility and, almost certainly, their condition as the older notebooks would have become extremely worn out with constant use. It is thus not unreasonable to presume that his practice of composing such tracts pre-dates 1843, probably extending back to his return in 1836. It may even have begun as early as 1828, although there is no evidence to support this.

As the notebooks are well over three hundred in number, each containing about twenty pages, the work involved to prepare, draft and write out such an extensive volume of material would have been quite extraordinary, particularly as this seems to have been an ongoing process. The material presented in the notebooks all feature De Morgan's legible handwriting (although the contents of some are neater than others), with diagrams drawn with characteristic precision and clarity. De Morgan also had an idiosyncratic habit of pasting in printed material which he considered particularly relevant to the subject under consideration, these insertions usually consisting of an appropriate paper or *Penny Cyclopædia* article, usually by himself. For instance, tract 104 on the "Reduction of partial Differential Equations to Linear Form"⁶⁹ contains his paper 'On partial differential equations of the first order',⁷⁰ pasted in the back.

Judging from the sheer range of subject matter covered in these books, it is likely that, although today's collection is incomplete, it contains the great majority of De Morgan's mathematical tracts. Yet even if the notebooks now extant are but a fraction of those once in circulation amongst his students, they still give us a far clearer impression of his mathematical teaching than any official documentation ever could. Indeed, from the evidence afforded by published syllabi, the University College mathematics course does not appear to change during this period of De Morgan's tenure, and if, as before, we were forced to rely purely on prospectuses and examination papers, there would probably be

⁶⁷ University of London Library (hereafter ULL), MS. 775/175.

⁶⁸ ULL, MS. 775/176.

⁶⁹ ULL, MS. 775/190.

⁷⁰ Augustus De Morgan, On partial differential equations of the first order, *Cambridge and Dublin Mathematical Journal*, 7 (1852), 28-35.

little more to say about his mathematical tuition. However, the tracts reveal that he taught much more than was indicated in the college calendars. Furthermore, as has been mentioned, with the constant updating and renewal of these manuscripts to incorporate new material and different modes of presentation, De Morgan's course can be seen to be gradually evolving as time progressed, although he apparently saw no reason to update his original outline. Thus, officially, between 1836 and 1867, the course was as follows:

JUNIOR CLASS, LOWER DIVISION: i) Arithmetic and the arithmetical theory of proportion
 ii) Euclid, Books 1-4
 iii) 6th Book of Euclid
 iv) First book of Solid Geometry in Lardner's Euclid
 v) Algebra, arithmetically considered, up to equations of the first degree.

JUNIOR CLASS, HIGHER DIVISION: i) Euclid, Books 5 and 6
 ii) First book of Solid Geometry in Lardner's Euclid
 iii) A review of the principles and operations of arithmetic
 iv) Algebra (including the nature and use of logarithms)
 v) Plane trigonometry (including mensuration).

SENIOR CLASS, LOWER DIVISION: i) Spherical trigonometry
 ii) Conic sections
 iii) Application of algebra to geometry
 iv) Higher parts of algebra
 v) Differential and integral calculus.

SENIOR CLASS, HIGHER DIVISION: Extension of subjects in the Lower Senior Class.
 "Subjects which all must learn who wish to become analysts, whether for Engineering or any other pursuit."⁷¹

Yet, incomplete though the college calendars' course summaries are, they do give us an excellent idea of De Morgan's conception of how his students should approach their subject, containing a further reiteration of his views on the (in)utility of lectures:

The Professor takes this opportunity to remind all who enter his Class, that nothing can be more erroneous than the impression that

⁷¹ a) *University College, London. Session 1839-40. Faculty of Arts and Laws*, (London: Richard and John E. Taylor, 1839), 6-7; b) *The University College London Calendar for the Session 1853-4*, (London: Walton & Maberly, 1853), 7-8, 23-4; c) *University College, London. Calendar. Session 1866-67*, (London: Walton & Maberly, 1866), 19, 35.

much can be done by merely attending the Lectures. Unless such attendance be accompanied by regular Study of the Books recommended, and attention to the Exercises given out in the Class-room, he cannot guarantee that any pupil shall find himself able to keep up with the Class.⁷²

What now follows is a survey of the material contained in the existing tracts to give some idea of what a student of mathematics at University College could have expected to study under De Morgan.

4.2.2 The Lower Junior Class

Of the 327 surviving notebooks, only ten contain material designed for the use of students in De Morgan's lower junior class. This is not altogether surprising when it is remembered that, not only was the subject matter covered far less extensive than in succeeding classes, but also that, in the mode of tuition adopted by the Professor for this class, oral lectures occupied a very small place, the majority of the time being devoted to giving written exercises and answering students' questions. Furthermore, for much of the relevant material, textbooks already existed which were perfectly adequate for this introductory level, such as his own *Elements of Arithmetic* and *Algebra*, and Lardner's edition of Euclid, while for the algebraical theory of proportion, he no doubt recommended his *Connexion of Number and Magnitude*.

What is most noticeable about these introductory tracts is the emphasis they place on the importance of a thorough knowledge and, above all, understanding of first principles. Whole notebooks are taken up with material defining elementary notions and correct procedures. For example, tract 157 is concerned entirely with elucidating the distinction between *abstract* and *concrete* arithmetic, with De Morgan distinguishing abstract numbers (e.g. 1, 64, $\frac{3}{4}$) from concrete numbers, which he defined as "magnitude represented by number"⁷³ (e.g. a line of 3 units length). Thus, his students learnt that, while one concrete number may be divided by another to give an abstract number, they could not be multiplied together, although "the idea that a line can be multiplied by a line is not uncommon".⁷⁴ Consequently, he warned, "it is very common to confound multiplying the (numbers of inches in the) sides to get the (number of square inches in

⁷² *ibid*: a) 7; b) 8; c) 20.

⁷³ ULL, MS. 775/277, f.2.

⁷⁴ *ibid*, f.11.

the) area with multiplying the *sides* to get the *area*, an unmeaning phrase".⁷⁵

As well as giving alternative presentations of material which could be found in the students' books, the tracts dealt in some considerable depth with matters with which most textbooks (even De Morgan's) did not concern themselves. One of the most fascinating tracts (110 - comprising three notebooks) was designed to be read before the student opened the first page of Euclid's *Elements*. Entitled "Notions preliminary to Geometry",⁷⁶ it illustrates De Morgan's desire for his students to be acquainted from the very start with the philosophical and epistemological issues relating to the subject. More significantly, being an introduction to the theory and practice of logic, it demonstrates his belief that a thorough grounding in logical notions and processes was essential for the geometrical novice, as he had maintained in his articles for the *Quarterly Journal of Education*.

The tract's first notebook begins with definitions, although, amusingly enough, the first two subjects, Space and Time, are described as "Undefinable. Known to all."⁷⁷ Similarly, his definition of Thought reads: "Equally undefinable with *space* and *time*."⁷⁸ After this somewhat peculiar beginning, he then proceeds to a more substantial explication of the laws which govern space, time and thought, eventually defining geometry as "the application of the necessary laws of thought to the investigation of the necessary laws of space".⁷⁹ It was the use of these laws of thought which he defined as reasoning, and it was with the goal of initiating his students into the practice of reasoning by logical deduction that the second notebook was primarily concerned.

As we have seen, De Morgan was wont to complain about the lack of contact between the disciplines of mathematics and logic: "Geometers have seldom been very *formal* logicians; and their patent of exemption was signed by Euclid."⁸⁰ In an attempt to remedy this defect in his students, this tract is dominated by lengthy discussions of logical notions and related issues. Definitions of self-evidence, axiom, postulate, problem and theorem are followed by an introduction to the syllogistic form and the four main logical propositions, viz.

⁷⁵ *ibid*, f.12.

⁷⁶ ULL, MS. 775/201, front cover.

⁷⁷ *ibid*, f.1.

⁷⁸ *ibid*.

⁷⁹ *ibid*, f.3.

⁸⁰ Augustus De Morgan, On indirect demonstration, *Philosophical Magazine*, (4), 3 (1852), 435-438, p.435.

A	Universal Affirmative	Every X is Y
I	Particular Affirmative	Some Xs are Ys
E	Universal Negative	No X is Y
O	Particular Negative	Some Xs are not Ys. ⁸¹

The next step before coming to actual geometrical demonstrations was to introduce his students to the concept of a proof. "A proposition," he wrote, "may be proved in two ways: Directly, by showing that it *is true*. Indirectly, by showing that the contradiction *is false*."⁸² Since the latter was conceptually the most difficult for the beginner, this tract was principally concerned with this mode of procedure, which "forces an absurd result out of the contradiction, and therefore forces the denial of the contradiction, or the affirmation of the proposition".⁸³ To illustrate this, De Morgan provided his students with a Euclidean demonstration of a universal affirmative proved by contradicting its particular negative. The example he chose was Book I proposition 6, which states that if a triangle has two equal angles, then the two subtending sides are also equal. The proof is as follows:

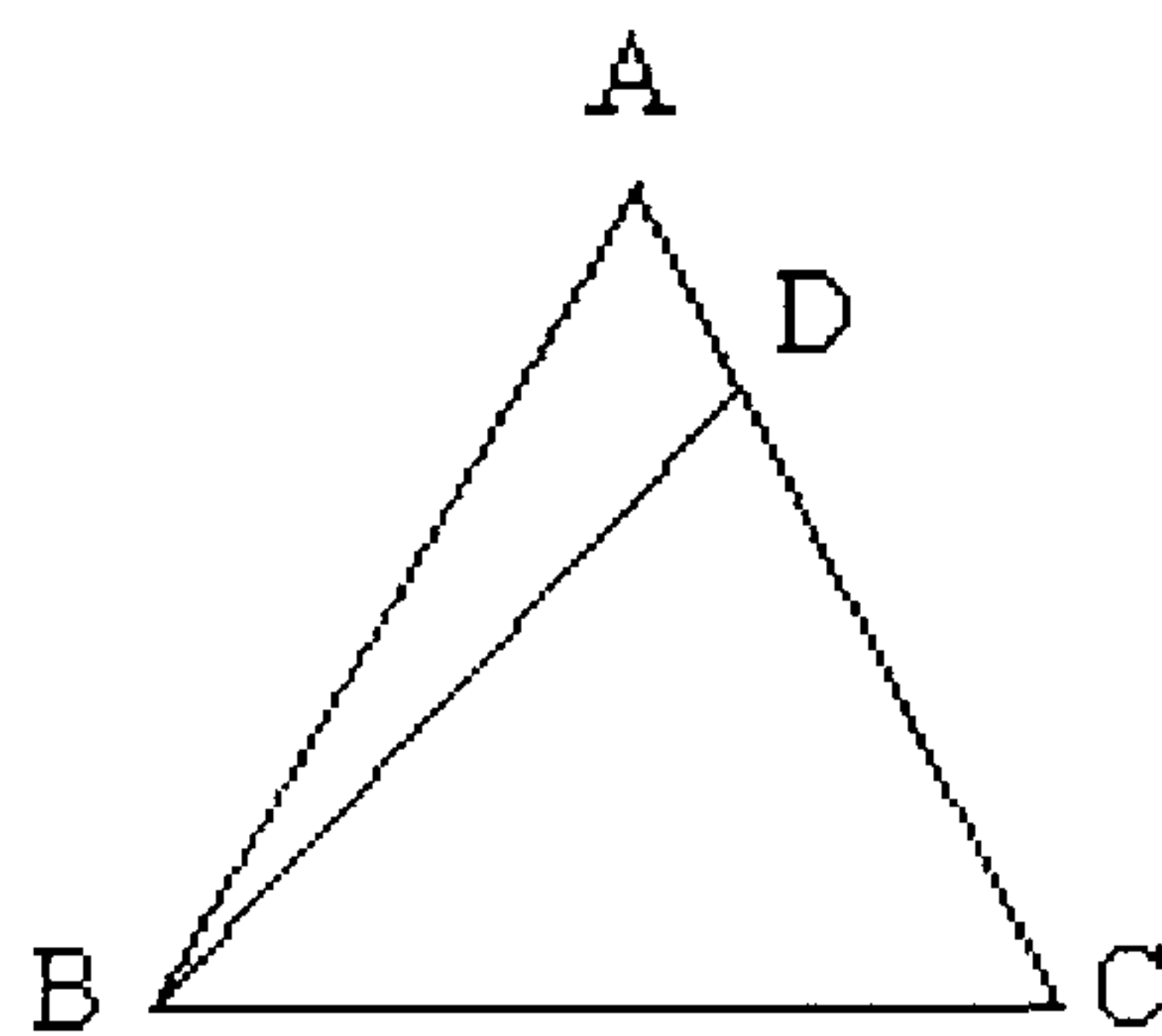


Figure 1

Let $\angle ABC = \angle ACB$, and suppose that $AC \neq AB$. If $AC > AB$ and $CD = AB$, then $\triangle BCD < \triangle ABC$. But, since the sides AB and BC are respectively equal to DC and CB , and, by the initial hypothesis, $\angle DCB = \angle ABC$, it follows that the base $DB =$ base AC and $\triangle BCD = \triangle ABC$. This, of course, gives a contradiction which proves the initial assumption ($AC \neq AB$) to be false, therefore $AC = AB$. In other words, De Morgan explained, the statement that "Some triangles (or one at least) having equal angles at the base are not isosceles"⁸⁴ has been contradicted, resulting in the validity of the original proposition.

⁸¹ Note that propositions A and O are mutually contradictory, as are E and I.

⁸² ULL, MS. 775/202, f.8.

⁸³ *ibid*, f.9.

⁸⁴ *ibid*, ff.9-10.

However, he noted that this was not the only conclusion which could be drawn from the above train of reasoning. The theorem also provides equally valid proof that if two sides of a triangle are unequal, so too are their inclosed angles, which is the *contrapositive* form of the same assertion. He drew particular attention to these forms of propositions, particularly in the case of the universal affirmative. For example, while the statement "Every A is B" is equivalent to "Every not-B is not-A", one cannot necessarily deduce that every not-A is not-B or even that every B is A. To use De Morgan's own example: "Divide all men into tall and short, and all men into good and bad. If, having made this division, we say all tall men are good, we do *not* say all short men are bad, but we do say that all bad men are short."⁸⁵ Learning to recognise identical statements couched in contrapositive forms was, in his opinion, a vital skill to acquire before tackling Euclid.

4.2.3 The Higher Junior Class

On progressing to De Morgan's higher junior class, his students were expected to be fully familiar with Euclidean deductive reasoning as far as the fourth book of the *Elements*. Yet, as he had expressed to his fellow mathematics teachers in the 1830s, he considered the style of Euclid's fifth book to be slightly too abstruse for the minds of his elementary students. For this reason, he had substituted the simpler arithmetical doctrine of proportion for his lower juniors, to prepare them for the more involved treatment with which the next division would begin. However, since the subject was one of no small difficulty, he was careful in his teaching to make it as comprehensible and clearly-defined as possible.

Some indication of how important De Morgan considered the topic was that the tract on ratio and proportion fills eleven notebooks, although four are duplicates. Like that on logic for the lower junior class, this tract, entitled "First Notions of Ratio", was written explicitly to be read prior to the study of Euclid Book 5. "*Ratio*," it began, "is one of those terms of mathematics which cannot be explained by any more simple term. It may be translated by the words *relative magnitude*."⁸⁶ De Morgan represented this concept in the following way:

Let there be two magnitudes of the same kind, say lines, A and B: and let the *multiples* of these lines be taken, as twice A, three times A, &c, or 2A,

⁸⁵ ULL, MS. 775/203, f.2.

⁸⁶ ULL, MS. 775/8, f.1.

3A, &c and 2B, 3B, &c. Let these multiples be all set off on the same line, from the same commencement

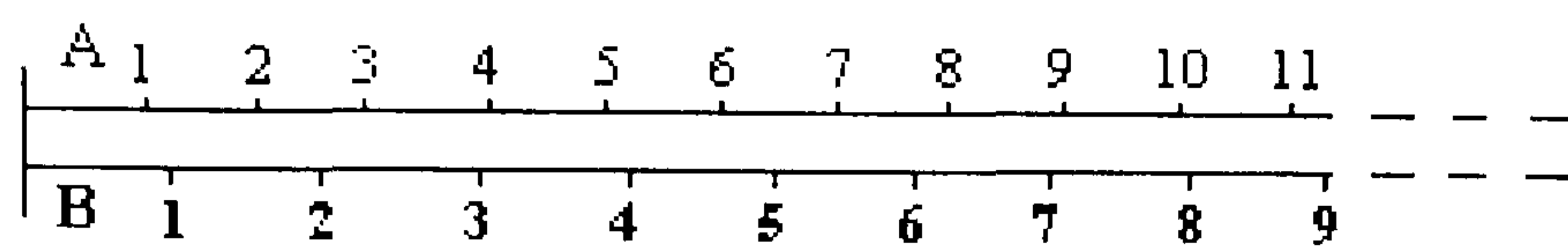


Figure 2

... and then let them be written down in order of magnitude

A B 2A 2B 3A 3B 4A 5A 4B 6A 5B 7A 6B 8A 7B 9A 10A....

Let this arrangement, continued ad *infinitum*, be called the *scale of relation* of A and B.⁸⁷

The use of these relative scales enabled the ratio of two magnitudes to be assigned. Furthermore, it also lessened the problem of incommensurable magnitudes - always a considerable obstacle to the beginner - by providing an accurate way of determining irrational relations: "By comparison of relative scales, ... the ratios, or relative magnitudes of *incommensurable quantities*, though not capable of any but approximate expression, by the symbols of *common* arithmetic, can be made the objects of absolute demonstration."⁸⁸ This comparison of scales of relation formed the basis of De Morgan's theory of proportion, of which his definition was as follows:

A and B are to one another in the proportion of P and Q when A is expressed in terms of B by the same decimal fraction, *be it terminable or interminable*, which expresses P in terms of Q.⁸⁹

When the students finally came to read the fifth book itself, it was intended that tract 4₆ be used as a supplement in order to clarify certain sections and guide the order in which the propositions were considered. This must have been highly beneficial to the students as the original phrasing of propositions in Euclid clearly added unnecessary complexity to an already complicated subject. Take, for example, the second proposition: *If the first magnitude be the same multiple of the second that the third is of the fourth, and the fifth the same multiple of the second that the sixth is of the fourth; then shall the first*

⁸⁷ ULL, MS. 775/10, f.1.

⁸⁸ *ibid*, f.15.

⁸⁹ ULL, MS. 775/14, ff.7-8. This arithmetical definition of proportion was, of course, equivalent to Euclid's geometrical version, much of tract 4₄ being taken up with De Morgan's proof of this.

together with the fifth be the same multiple of the second, that the third together with the sixth is of the fourth. Now compare this to De Morgan's 'translation':

Prop.2. It means that if $A = mB$, $C = mD$, $E = nB$, $F = nD$,
 $A + E = (m + n)B$, $C + F = (m + n)D$, or $A + E$ is the same multiple of B which $C + F$ is of D . Remember that the Italic letters stand for *numbers*: thus mD means *m times the magnitude D*.⁹⁰

De Morgan's alternative presentation thus attempted to simplify the somewhat confusing statements and demonstrations of the fifth book by exhibiting them in a far more palatable form. In addition to this, he also recommended that his students read several of his articles in the *Penny Cyclopædia* relating to the subject.⁹¹ The study of these articles, together with this tract and his similar exposition in the *Connexion of Number and Magnitude* would, he believed, render Euclid's fifth book far more intelligible to his junior students than if he had left them to study it unaided.⁹²

In his treatment of Euclidean solid geometry, De Morgan similarly attempted to present the material in a slightly less convoluted way than the original, although this time, the presentation is not his own, his principal sources being Lardner's Euclid and Legendre's *Geometry*. However, while the majority of the material covered under the heading of solid geometry was primarily derived from Euclid Book 11, perhaps the most interesting topic treated, while it stemmed originally from Euclid, was an introduction to far more recent geometrical thinking. One of the tracts, bearing the title "On Euclid's definition of Equal Solids", is a fascinating treatment of recent work on what would now be called topology, being a discussion of the distinction between the polygon and the solid polyhedron:

A polygon of more than three sides may shift its figure without altering any side, and without severing the junction of any two sides. But a polyhedron cannot shift its figure without either alteration of the faces, or breaking at the edges. Thus the cube cannot cease to be a cube as long as the faces remain squares. ...

This remarkable distinction between plane and solid figures was seen by Euclid: but Euclid could not demonstrate that the faces and their relative arrangements determine the solid. He evaded the difficulty in a manner

⁹⁰ ULL, MS. 775/17, f.1.

⁹¹ E.g. Proportion, [19 (1841), 49-53]; Incommensurables, theory of, [12 (1838), 455-456].

⁹² Interestingly, the theory of ratio and proportion was a principal research interest of M. J. M. Hill (1856-1929), professor of pure mathematics at University College from 1884-1923. He will be discussed in Chapter 6.

unworthy of himself. He could not *prove* that if two solids have the same number of plane faces equal each to each, and similarly juxtaposed, those solids are equal in all respects. He ought therefore to have made it a *postulate*: but he made it a *definition*. He says *equal* (and similar) solids *are* those which are bounded by the same number of faces equal and similar each to each. But it must be said for Euclid that he does not afterwards employ this definition except in cases in which he has proved, or could very easily prove, the theorem which it evades.⁹³

He then gives his students Cauchy's (rather lengthy) proof of the theorem, involving several lemmas and preliminary theorems, including Euler's famous result that "In any solid figure, the number of edges is two more than the number of corners and faces together; $C + F = E + 2$ ".⁹⁴

Having dwelt extensively on Euclidean-related matters, the higher junior class would have then turned their attention to a recapitulation of the rules and procedures of arithmetic before being initiated into abstract algebra. As the above syllabus indicates, the lower junior class would have already practised linear equations, but these were treated more as features of a universal arithmetic than a general algebra. Now, the class was ready to learn the distinction between the two:

In *Arithmetic* every symbol of magnitude, that is, every symbol of which we say it may stand for more or less, represents a *number*, and nothing but a number... In *Algebra*, a symbol of magnitude is a symbol of something else besides magnitude, a symbol of magnitude with some amount of interpretation as to *what sort* of magnitude, a number with some amount of indication *what of*.... Algebra employs the *symbols*, the *language* and the *rules* of arithmetic. But...no letter *a* has its full meaning described until we are told both its *value* and its *sign*. In an *actual problem* we must also know the *meaning* of the sign: but in the *mere calculation*, we need know no more than the sign.⁹⁵

The algebra to which De Morgan's students were being introduced was a long way from the highly evolved structural algebra of today. Yet, as a component in the development of abstract algebra, it was to play a significant role, furthering the trend of abstraction prevalent in preceding and contemporary algebras such as that of his friend and former tutor George Peacock.⁹⁶ However, whereas in Peacock's *Algebra* the symbols were

⁹³ ULL, MS. 775/280, ff.1, 2-3.

⁹⁴ *ibid*, f.8.

⁹⁵ ULL, MS. 775/271, ff.1, 4.

⁹⁶ Published in his *Treatise on Algebra* (1830, and an enlarged version of 1842).

generally understood to represent numbers or magnitudes, De Morgan would deliberately keep them abstract, as the following extract from his *Trigonometry and Double Algebra* explains:

In abandoning the meaning of symbols, we also abandon those of the words which describe them. Thus *addition* is to be, for the present, a sound void of sense. It is a mode of combination represented by +; when + receives its meaning, so also will the word *addition*. It is most important that the student should bear in mind that, *with one exception*, no word or sign of arithmetic or algebra has one atom of meaning throughout this chapter... If any one were to assert that + and – might mean reward and punishment, and A, B, C, etc, might stand for virtues and vices, the reader might believe him, or contradict him, as he pleases - but not out of *this* chapter. The one exception above noted, which has some share of meaning, is the sign = placed between two symbols as in $A=B$. It indicates that the two symbols have the same resulting meaning, by whatever steps attained. That A and B, if quantities, are the same amount of quantity; that if operations, they are of the same effect, etc.⁹⁷

This was the algebra he presented to his students: a purely formalist view where symbols, if combined by correct procedures, would give valid results, regardless of the meaning or interpretation one placed on them. The above excerpt illustrates his view of this form of symbolic algebra which, as Helena Pycior correctly points out, he saw "as an essential step from universal arithmetic to meaningful algebra".⁹⁸ Yet his symbolic algebra had many different levels. The first was the universal arithmetic taught to his lower juniors, whereby symbols are used to represent numbers; the second stage he denoted as *single algebra* where symbols can be represented on a straight line passing through an origin, each symbol denoting a quantity forwards or backwards: hence in this system, unlike universal arithmetic, negative numbers are perfectly possible. But what about the validity of imaginary or complex numbers? In his tract, De Morgan gave the following answer:

We shall not say that -1 has no square root: but only that it has no square root in the system of algebra which only considers *opposites*, and has only *positive* and *negative* for its divisions of quantity. If we call it *impossible*, we mean only impossible under our present definitions. Thus $8-11$ was *impossible* in arithmetic: under our present meanings it is possible, and signifies -3 , or three of the sort opposite to those which are signified by

⁹⁷ Augustus De Morgan, *Trigonometry and Double Algebra*, (London: Taylor, Walton, & Maberly, 1849), 101.

⁹⁸ Helena M. Pycior, Augustus De Morgan's Algebraic Work: The Three Stages, *Isis*, **74** (1983), 211-226, p.221.

+1. And in like manner it may happen that in a wider system of algebra $\sqrt{-1}$, now impossible, may have an intelligible meaning.⁹⁹

De Morgan called this wider system *double algebra*. It was an area to which he was to devote much research, although, being too advanced for his junior classes, he deferred its discussion until his pupils had reached his senior class - as we shall see.

Now that they were familiar with algebraic terminology and ideas, the students were ready to progress to the solution of quadratic, cubic and higher order equations in one or more unknown. Once again, De Morgan's lectures were complemented by his relevant publications, especially his *Elements of Algebra* (1835), and numerous related tracts giving further elucidation and hints with problems. It was at this stage that students would have first come across the binomial theorem, leading immediately to the study of series, both finite and infinite. This in turn led to considerations of convergent and divergent series, resulting in their introduction to one of the most crucial mathematical concepts, recently reinstated in analysis: the limit.

As mentioned in section 1.3.2, earlier in the century the Analytical Society had been instrumental in replacing Newton's fluxional calculus with the algebraic method of Lagrange, thus rejecting a system based (albeit very dubiously) on the notion of a limit. This concept had been re-formulated by the Frenchman Augustin-Louis Cauchy (1789-1857) in the early 1820s, but was not immediately accepted in France or elsewhere. De Morgan's *Elements of Algebra* was significant in that it was the first English work to contain a definition of the continuity of a mathematical function using limits. Following the appearance of this work De Morgan had spent the next six years (1836-42) compiling his monumental treatise on *The Differential and Integral Calculus*, which was published by the SDUK in twenty-five instalments, numbering 785 closely-printed pages in total. The most comprehensive volume on the subject for over a generation, the whole of this work is grounded on the concept of limits, its preface containing De Morgan's defence of his adoption of the new approach:

The method of Lagrange, founded on a very defective demonstration of the possibility of expanding $\phi(x + h)$ in whole powers of h , ... was the sacrifice of the clear and indubitable principle of limits to a phantom, the idea that an Algebra without limits was purer than one in which that notion was introduced. But, independently of the idea of limit being

⁹⁹ *op. cit.*, (95), f.15.

absolutely necessary even to the proper conception of a convergent series, it must have been obvious enough to Lagrange himself that all application of the science to concrete magnitude, even on his own system, required the theory of limits.¹⁰⁰

The reason for the initial lack of enthusiasm for the new system was its considerable difficulty, not least in rigorously defining precisely what a limit actually was. For this reason, De Morgan devoted a whole tract to providing a thorough and intelligible definition, together with numerous illustrations. Since his students would now be familiar with incommensurability, the first example used was the length of the diagonal in a unit square.

$\sqrt{2}$ is the limit we perpetually approach, and to any degree of nearness we please, but which we never reach, by summing

$$1 + \frac{4}{10} + \frac{1}{100} + \frac{4}{1000} + \frac{2}{10000} + \frac{1}{100000} + \dots$$

Or thus $\sqrt{2}$ is $1 + \frac{1}{2 + \frac{1}{2 + \frac{1}{2 + \dots}}}$, being the limit we perpetually approach by

passing from one fraction to another in $1 \frac{3}{2} \frac{7}{5} \frac{17}{12} \frac{41}{29} \frac{99}{70} \frac{239}{169} \frac{571}{408} \dots$ ¹⁰¹

But, he said, it was meaningless to ask what this limit actually was "because this process will not tell us what it *is*, but only what is near to it, the degree of nearness being at our pleasure. 'What *is* the limit' is the same question as 'What is the exact expression for that which does not admit of exact expression'."¹⁰² What then was the point of introducing limits in the first place? "We introduce them because we cannot do without them, being all the time perfectly willing to do without them if any one will show us how."¹⁰³ Yet despite these reservations, De Morgan was nonetheless firmly convinced of their epistemological soundness and, as one of the first in Britain to publish and teach mathematics using limits, his work helped establish this concept as the basis of modern mathematical analysis.

The use of limits also formed the basis of his introduction to logarithms as well as his teaching of trigonometrical analysis, where he employed limits to analyse the various properties of expressions such as $\frac{\sin x}{x}$ and $\frac{1 - \cos x}{x^2}$. His tracts on trigonometry for this

¹⁰⁰ Augustus De Morgan, *The Differential and Integral Calculus*, (London: SDUK, 1842), iv-v.

¹⁰¹ ULL, MS. 775/284, f.2.

¹⁰² *ibid.*

¹⁰³ *ibid.*, f.3.

class began with the usual problems of plane trigonometry such as finding values of angles and sides given certain information, progressing to questions involving multiple angles and inverse functions. Again, he published a book, *Elements of Trigonometry and Trigonometrical Analysis* (1837), for his students to use, which was later supplemented by the first half of *Trigonometry and Double Algebra*. But he continued to compile additional tracts, adding further explanations and alternative demonstrations to the mass of information already available to the students. For example, in 1857 he wrote a new tract containing a proof of the double angle formulae "more easy than that given in my work on Trigonometry".¹⁰⁴

These were the topics studied by students in De Morgan's higher junior class, as specified by the published syllabus. However, perusal of the existing tracts reveals that, unofficially at least, these students were also given instruction in at least four other areas. Two of these subjects came under the category of 'applied' arithmetic, the first being interest and annuities. Interest, both simple and compound, had been covered by De Morgan in his *Elements of Arithmetic* in its section on commercial applications,¹⁰⁵ but his tracts on the subject extended this treatment to include the rudiments of actuarial mathematics, with which he was obviously well acquainted. In particular, they introduced the students to the quite complex calculation of annuities based on various mortality tables. Once again, students were recommended to search out articles in the *Penny Cyclopædia* for extra information, those on 'Rebate' and 'Mortality' being deemed especially useful.¹⁰⁶

The elements of the theory of permutations and combinations had also been introduced in De Morgan's *Arithmetic*, in the main text and in an appendix added to the fifth edition.¹⁰⁷ One would assume that, as lower juniors, students would have been expected to read this book and thus be aware of its contents. Thus, by the time they reached the higher junior class, they would be familiar with the rudiments of the subject and ready for the more advanced treatment contained in his tracts. These extended the methods previously learnt, giving the subject a more algebraic approach and leading directly to elementary problems

¹⁰⁴ ULL, MS. 775/285, f.1.

¹⁰⁵ Augustus De Morgan, *The Elements of Arithmetic*, 5th edition, (London: Taylor, Walton and Maberly, 1853), 150-160.

¹⁰⁶ One of the tracts (MS. 775/149) contains a copy of De Morgan's paper 'On the demonstration of formulae connected with interest and annuities', *Assurance Magazine and Journal of the Institute of Actuaries*, 4 (1854), 277-82.

¹⁰⁷ A. De Morgan, *op. cit.*, (105), 118-123, 201-210.

in probability theory. Interestingly, for many of the exercises he set in this subject, he relied on a popular algebra primer written by one of his former students, Isaac Todhunter,¹⁰⁸ who, by the 1850s had become a successful author of mathematical textbooks.¹⁰⁹

Additional geometrical topics were also begun in this class, albeit at a fairly introductory level, the first being algebraic geometry, where students were merely introduced to the concept of representing curves algebraically using the simplest examples such as the straight line and circle. At this stage, problems set primarily involved either tracing curves or finding the intersection of two lines by solving simultaneous equations. Their initiation into projective geometry reached a slightly higher stage, proceeding as far as Pascal's and Brianchon's theorems. However, both topics would presumably have been reached at the very end of the academic year, perhaps on the occasions when De Morgan had completed the rest of his higher junior syllabus - they, and much more besides, would be treated in full in his lower senior class.

4.2.4 The Lower Senior Class

By the time they entered the lower division of De Morgan's senior class, the majority of his students would have completed at least one year of mathematical study. As can be gleaned from the preceding sections, that year would have provided the students with a study programme of considerable intensity, especially since mathematics was far from being the sole subject of the undergraduate syllabus at University College. However, this pales in comparison with the level of material covered during the following year, as illustrated by the number of relevant notebooks still in existence: in comparison to the 80 such documents relating to junior class subject matter, there are no fewer than 247 notebooks concerning material covered by the two divisions of the senior class.

According to published sources at least, the lower senior course began with an introduction to spherical trigonometry. Again, De Morgan's tracts on this topic supplemented both his lectures and a book on the subject - in this case, a small textbook he had written for the SDUK in 1834. His tracts included further explanation and examples of various points, including a discussion of various properties of the sphere,

¹⁰⁸ Isaac Todhunter, *Algebra for the use of colleges and schools*, (Cambridge: Macmillan and Co., 1858).

¹⁰⁹ See the next chapter.

which De Morgan dwelt upon before beginning the study of spherical triangles, in many cases setting them as homework questions for the class, for example:

If a point P be at a quadrant distance from each of two points A, B (not opposite) of a circle, then P is a pole of AB.¹¹⁰ Prove this.¹¹¹

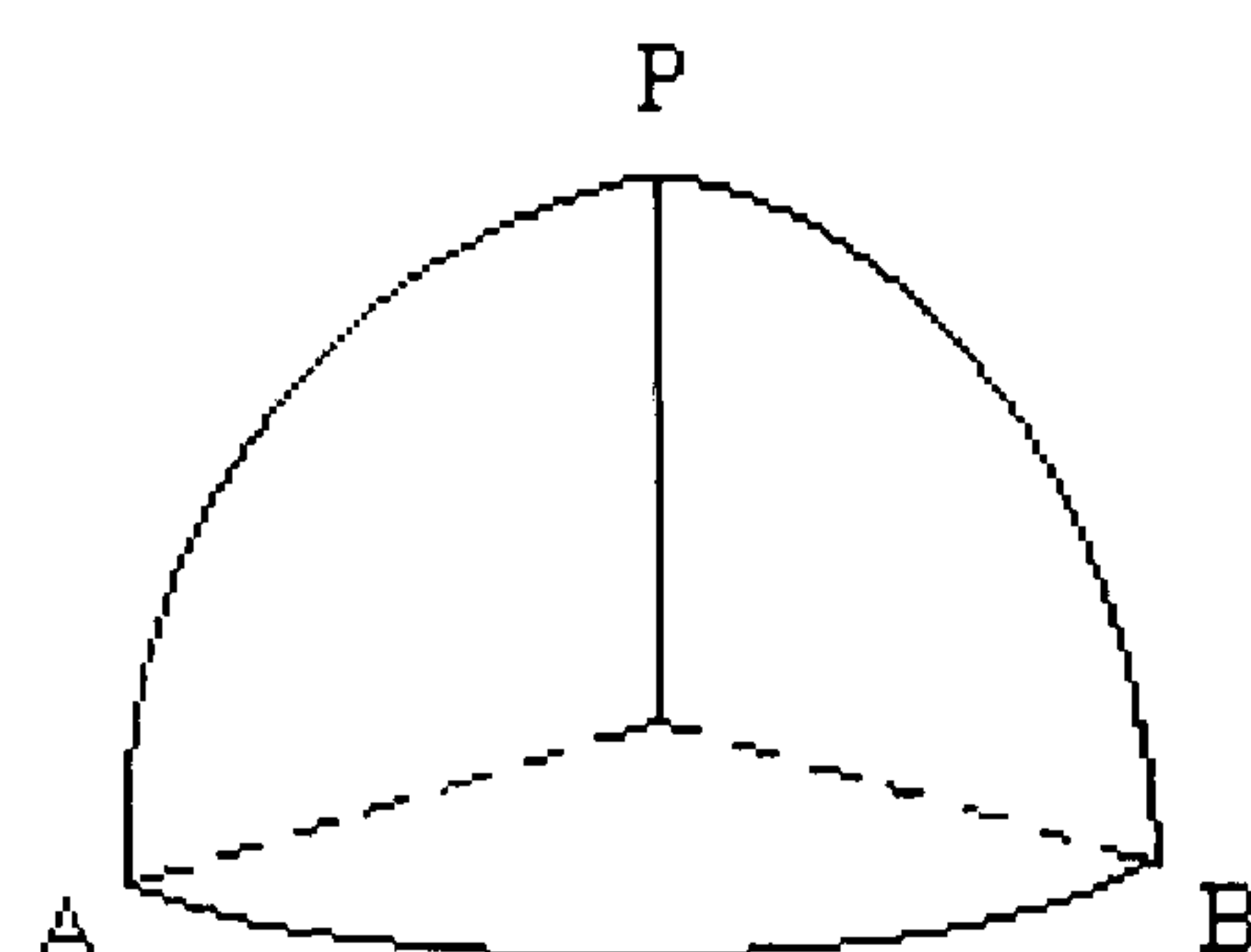


Figure 3

Following these preliminaries, which also included the obligatory definitions of terms such as great circle, lune, and polar triangle, he would proceed to statements and proofs of the standard formulae for spherical triangles (i.e. $\cos c = \cos a \cos b$, $\sin a = \sin c \sin A$, $\tan b = \tan c \cos A$, etc), before considering problems such as finding areas, inscribing and circumscribing circles, and supplemental triangles.

As far as can be ascertained from the tracts, De Morgan's teaching of spherical trigonometry appears to have been more or less self-contained. In other words, he does not seem to have relied on it for many other topics, and its results are rarely referred to in notebooks concerning subsequent subjects. This is presumably because few other mathematical topics were dependent on it, the major exception to this being the study of astronomy, which in any case was not in De Morgan's domain, being taught by his colleague in the chair of natural philosophy. In addition, as can be seen above, spherical trigonometry was not listed in the University of London mathematical syllabus. However, no doubt refusing to have his course dictated by an external body, De Morgan included it for the sake of completeness, although he devoted less time to its consideration than other more essential topics.

¹¹⁰ De Morgan gave the following definition(s): "A pole is at the same *distance* (distance, on a sphere, is always measured on the arc of a great circle) from every point of one of its circles. And in a great circle, this distance is always a *quadrant* (quarter of a circumference)."

¹¹¹ ULL, MS. 775/287, f.3.

By contrast, one of the dominant subjects of the lower senior class was conic sections, which provided the basis for his tuition of both projective and algebraic geometry. Not surprisingly, therefore, compared to just five items on spherical trigonometry, the number of individual notebooks containing material relating to the conics is well over twenty; moreover, De Morgan's treatment often varies from tract to tract. To begin with, the ellipse, parabola and hyperbola would have been introduced purely geometrically, with particular attention being paid to clearly defining features such as the axis, vertex and the latus rectum. Once again, all tuition was accompanied by regular exercises which, at this stage, required purely geometrical solutions.

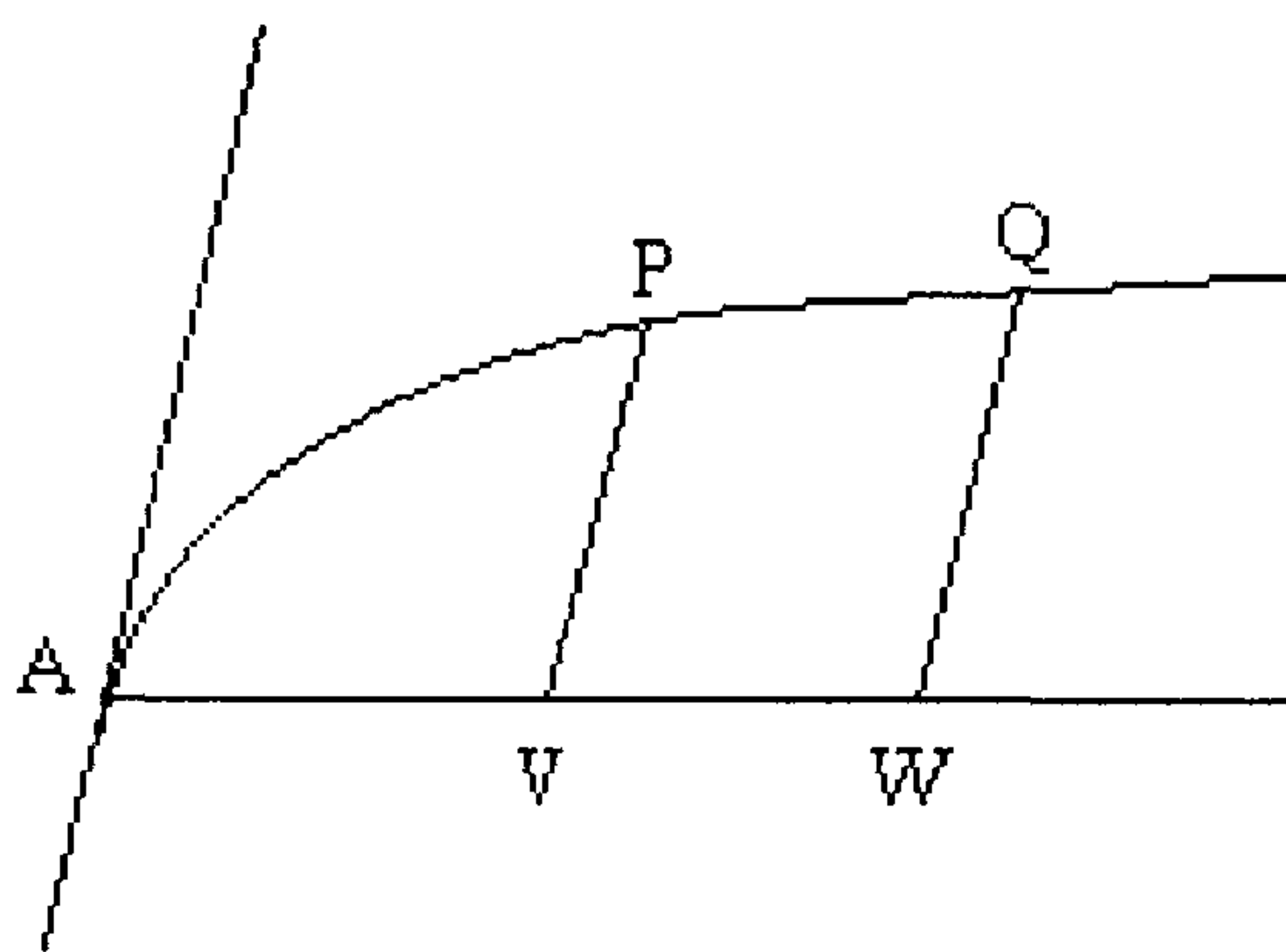


Figure 4

Show that if AW meets the curve again at an infinite distance, and if PV, QW be parallel to the tangent at A; then

$$\frac{PV^2}{AV} = \frac{QW^2}{AW}. \quad 112$$

Once his students had acquired a familiarity with the conics, De Morgan would then introduce the closely-related topic of projective geometry although, judging from the tracts written for the higher junior class, they would have already have received some introduction to the rudiments of the subject by this time. However, as with spherical trigonometry, knowledge of projective geometry was not an explicit requirement for a University of London degree, yet a considerable number of tracts deal with this topic, despite its absence from the B.A. syllabus. De Morgan's justification was that "the method of projections establishes the more general and more difficult properties of the conic sections (as here seen) with greater ease than the ordinary methods establish the more easy properties of those same curves".¹¹³ This he illustrated by the example: "if

¹¹² ULL, MS. 775/70, f.15.

¹¹³ ULL, MS. 775/261, inside front cover.

three tangents be circumscribed about any conic section, the three lines joining the intersections to the opposite points of contact meet in one point".¹¹⁴

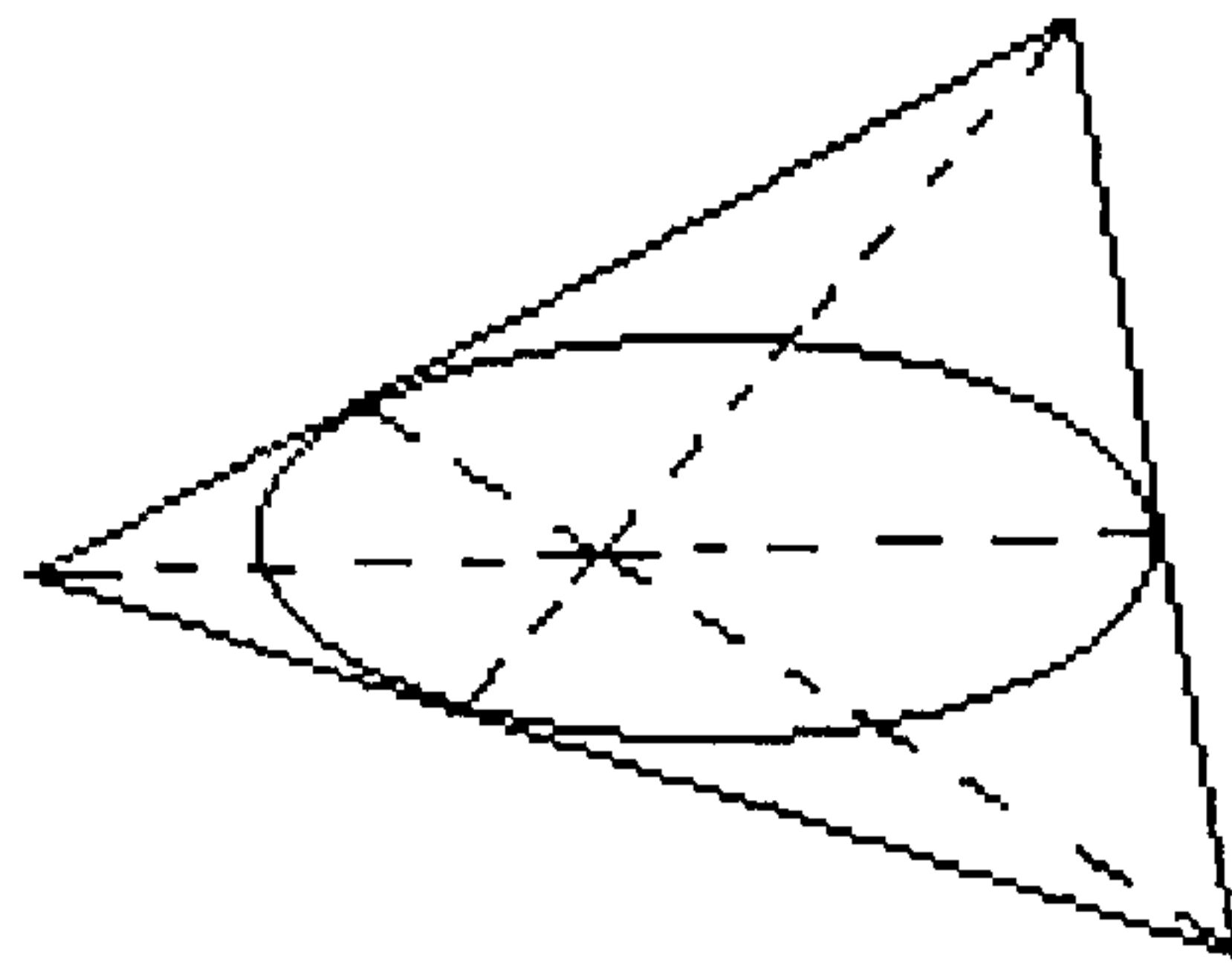


Figure 5

De Morgan's course on projective geometry largely consisted of an analysis of various properties and peculiarities of projective figures, such as colinearity and involution. As with his initial approach to conic sections, his treatment of the subject was entirely geometrical, with all demonstrations relying on neatly drawn diagrams and Euclidean-style proofs. Yet he believed that students should not be taught merely to establish propositions on paper, being keenly aware of their need to visualise projective figures if they were to understand the subject completely. To assist them in this, his tracts contained advice on how to formulate an appropriate mental image: "Suppose the eye to be at the *vertex of projection*, and the *plane of projection* to be a wall extending in front. The eye may be supposed applied at a glass plane parallel to the wall, which glass plane represents the *unprojected plane*. Then all points between the eye and the wall will be seen at their projections on the wall, and so would all the points behind the wall, if the latter were transparent."¹¹⁵

The most frequently stated (and proved) results in this section of the course were Pascal's and Brianchon's theorems, which appear in various formulations, together with alternative demonstrations and applications, in many different tracts. Yet almost all the applications considered are purely abstract and hypothetical, with no reference to the utility of perspective in the real world. Indeed, considering the conceivability that some of his students may later have trained to become architects or draughtsmen,¹¹⁶ it is perhaps surprising that almost no evidence exists to suggest that De Morgan gave them any information regarding practical applications of projective geometrical methods.

¹¹⁴ *ibid*, f.12.

¹¹⁵ ULL, MS. 775/73, f.2.

¹¹⁶ Particularly after 1841, when the first professorship of architecture in Britain was founded at University College. Its first occupant was Thomas Leverton Donaldson (1795-1885), who held the chair until 1865.

Moreover, the only notebook relating to its actual utility has nothing to do with architecture or graphic design, being an introductory tract entitled "First notions on Projection of Maps and Charts", in which De Morgan introduces the various methods of forming "a representation of some portion of the globe of the earth or heavens upon a plane",¹¹⁷ starting with conical projection, viz:

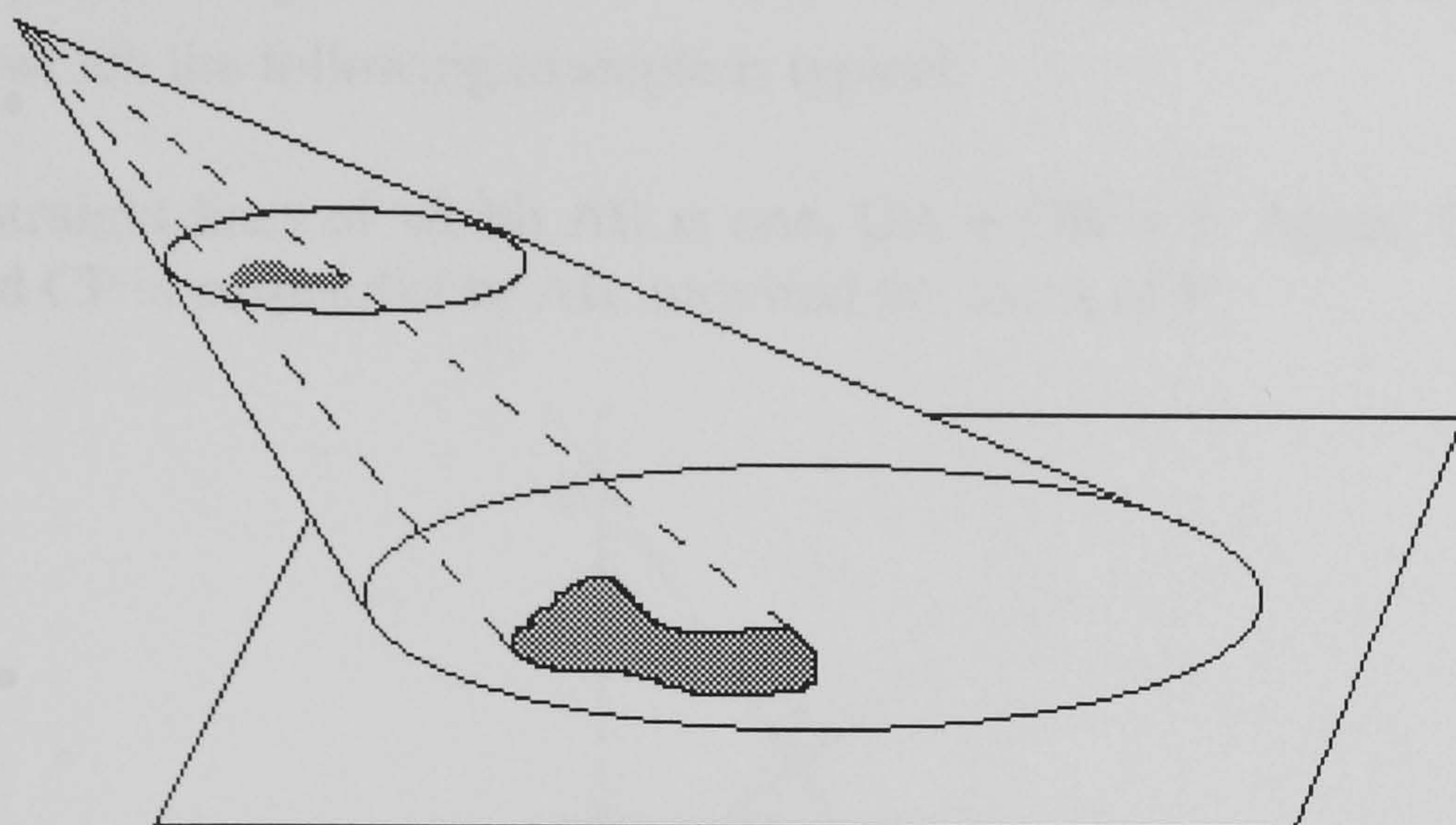


Figure 6

and moving on to brief descriptions of orthographic, gnomonic and stereographic projections.¹¹⁸ This tract would presumably have been of more use to those in his class aspiring to become apprentice cartographers than architects!

Now that the class had reached a considerable level of proficiency in projective geometry, De Morgan would employ algebraic geometry to give alternative demonstrations of similar - and, in some cases, the same - results. Having already defined straight lines and circles algebraically in the higher junior class, De Morgan's tuition at this level began with a discussion of the general second degree equation $ay^2 + bxy + cx^2 + dy + ex + f = 0$, considering the curves generated by its different variations. In such a way, he was able to give yet another introduction to the conic sections, extending the treatment to include algebraic treatments of results originally proved using projective geometry, including Pascal's and Brianchon's theorems.¹¹⁹

¹¹⁷ ULL, MS. 775/255, f.1.

¹¹⁸ Also included for further information is his *Penny Cyclopædia* article on Mercator's projection.

¹¹⁹ Much of De Morgan's treatment of conic sections in his tracts on algebraic geometry was taken directly from George Salmon's *Treatise on Conic Sections*, (Dublin: Hodges and Smith, 1847).

But instruction in algebraic geometry was not limited to verification of previously proved results. The class was also introduced to other features of the subject such as finding loci, asymptotes, normals and tangents to various curves. As with the material on conic sections, De Morgan's tracts on algebraic geometry are quite numerous, probably because he never published a textbook on the subject. This deficiency is, however, remedied by the plentiful supply of explanation and worked exercises provided in the notebooks on this subject, of which the following example is typical:

In the straight lines of which AB is one, $OA + OB = 1$. Again, C bisects OA, and CP is perpendicular to AB; required the locus of P.

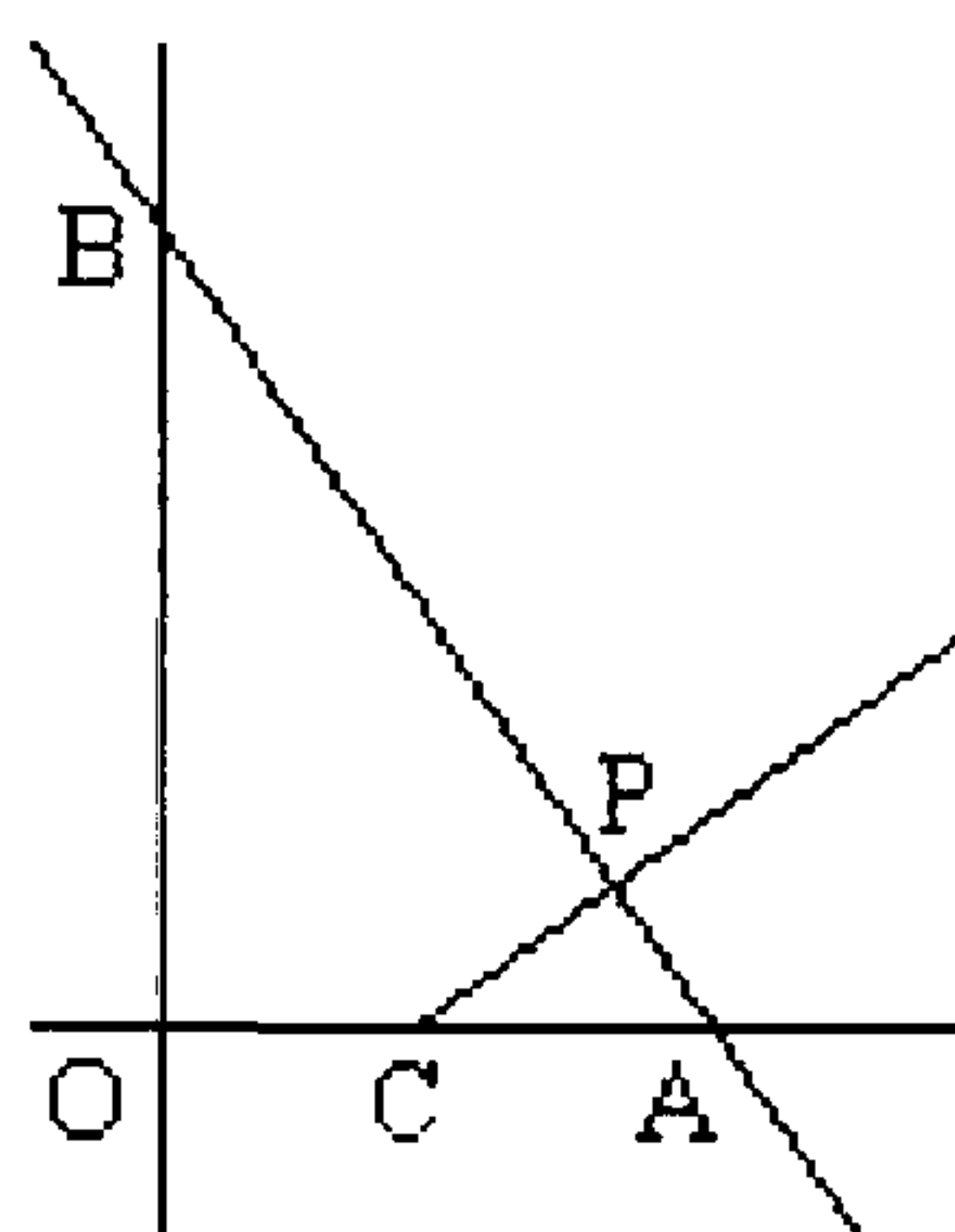


Figure 7

Let $OA = a$, $OB = 1 - a$

Equation of AB : $\frac{x}{a} + \frac{y}{1-a} = 1$

or $y = -\frac{1-a}{a}(x-a).$ (1)

CP, passing through $(\frac{1}{2}a, 0)$ and being perpendicular to AB, has the equation

$$y - 0 = \frac{a}{1-a}(x - \frac{1}{2}a) \text{ or } y = \frac{a}{1-a}(x - \frac{1}{2}a). \quad (2)$$

If we eliminate a from (1) and (2), we get an equation which is true at the point of intersection P, and, being independent of a , at all such points of intersection for all such pairs of lines. It belongs then to the curve required

$$(1) \quad a^2 + (y - x - 1)a + x = 0$$

$$(2) \quad a^2 - 2(x + y)a + 2y = 0$$

$$\therefore (3y + x - 1)a = 2y - x$$

$$\therefore \frac{(2y - x)^2}{(3y + x - 1)^2} - \frac{2(x + y)(2y - x)}{3y + x - 1} + 2y = 0$$

$$\therefore 6y^3 + (2x - 4)y^2 + (6x^2 - 6x + 2)y + 2x^3 - x^2 = 0. \quad 120$$

¹²⁰ ULL, MS. 775/159, f.10.

Obviously, at this stage the class would have been familiar with this level of algebraic manipulation; indeed, by this time, their exercises in algebra included multiplying and dividing polynomials and solving cubics using Cardan's and Ferrari's methods. Among other algorithms taught by De Morgan in the theory of equations was the more recent Horner's method,¹²¹ a procedure for approximating roots of equations with no exact solution. He later described his motivation for introducing this method, and the results his students obtained after applying it to the equation $x^3 - 2x = 5$:

In 1831, Fourier's posthumous work on equations¹²² showed 33 figures of solution, got with enormous labour. Thinking this a good opportunity to illustrate the superiority of the method of W. G. Horner, not yet known in France, and not much known in England, I proposed to one of my classes, in 1841, to beat Fourier on this point, as a Christmas exercise. I received several answers, agreeing with each other, to 50 places of decimals. In 1848, I repeated the proposal, requesting that 50 places might be exceeded: I obtained answers of 75, 65, 63, 58, 57, and 52 places. But one answer, by Mr. W. Harris Johnston, of Dundalk, and of the Excise Office, went to 101 decimal places. ... In 1851, another pupil of mine, Mr. J. Power Hicks,¹²³ carried the result to 152 decimal places, without knowing what Mr. Johnston had done. The result is in the *English Cyclopædia*, article INVOLUTION AND EVOLUTION.¹²⁴

It is here that we begin to detect a new feature in De Morgan's teaching, a characteristic which becomes especially noticeable in his lower senior algebra. This is a desire to acquaint the more advanced pupils with recent mathematical developments, (i.e. from the first half of the nineteenth century). Tract 25, for example, entitled "On the roots of Algebraical Expressions" contains material which, while ostensibly concerned with the theory of equations, would nowadays be considered as part of complex analysis, being straight from the pages of recent works by Cauchy and Jean-Robert Argand (1768-1822). It also includes several new proofs of the existence of a root in every equation, including a paper by De Morgan on the subject, pasted in the back as usual, although his advice to students was: "Read Argand first, and then examine Cauchy's".¹²⁵

¹²¹ Invented by William George Horner (1786-1837), a school-teacher from the West Country, and published in 1819.

¹²² Jean Baptiste Joseph Fourier, *Analyse des équations déterminées*, (Paris: Firmin Didot Frères, 1831), 209-217.

¹²³ See note 65.

¹²⁴ A. De Morgan, *op. cit.*, (63), 292-293.

¹²⁵ ULL, MS.775/55, f.17.

Complex analysis was, of course, close to his own research into double algebra - a system whereby complex numbers were perfectly legitimate and could be given a two-dimensional representation, as in an Argand diagram. In fact, much of De Morgan's algebraic research concentrated on constructing a three-dimensional or *triple* algebra using numbers of the form $a + bi + cj$, where i and j are imaginary. However, this attempt was eventually proved futile by his friend, the Irish mathematician and Astronomer Royal, Sir William Rowan Hamilton (1805-1865) who, in 1843, realised that a triple algebra of the form envisaged by De Morgan was impossible. Hamilton's discovery that four components were required ($a + bi + cj + dk$, where i, j and k are imaginary) provided the basis of his *quadruple algebra* or *quaternions*, which in turn served as the foundation of modern vector algebra. However, these developments would have perhaps been a little too advanced for the capabilities of the majority of De Morgan's students. For them, double algebra involved little more than drawing complex numbers on an axis and proving the Euler identities.

The lower seniors would, however, have been presented with many of the latest results in modern analysis, especially in their study of infinite series, where De Morgan's enthusiasm for acquainting his students with new findings is particularly evident.¹²⁶ His desire to incorporate alternative forms of demonstration into his course is exemplified by a tract written in 1862, towards the end of his career, containing a paper in which he gave not one but two simple proofs of the divergency of $1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \dots$:

Parcel it out as follows:-

$$1 + \frac{1}{2} + (\frac{1}{3} + \frac{1}{4}) + (\frac{1}{5} + \frac{1}{6} + \frac{1}{7} + \frac{1}{8}) + (\frac{1}{9} + \dots + \frac{1}{16}) + \dots$$

Each parcel is obviously more than half a unit. If then we want to exceed a million of millions, we have nothing to do but to sum two millions of millions of these lots. I mention this common proof that I may give another which I never found in a book, though it is not mine. It is well known that when $a - b + c - d + \dots$ consists of terms diminishing without limit, the series is convergent, with a limit between a and $a - b$. Now

$$1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \dots \text{ is } 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \dots \\ + 1 \quad + \frac{1}{2} + \dots$$

And if it be S , we have $S = a + S$, where a is finite. Hence S is infinite.¹²⁷

¹²⁶ For a discussion of De Morgan's contributions to analysis with regard to convergence of series, see Ivor Grattan-Guinness, *The development of the foundations of mathematical analysis from Euler to Riemann*, (Cambridge, Mass.: MIT Press, 1970), 148-149.

¹²⁷ Augustus De Morgan, On the summation of divergent series, *Assurance Magazine and Journal of the Institute of Actuaries*, **12** (1865), 245-252, p.246. A footnote, added immediately after the second proof, reads: "This ingenious proof was given me, 37 years ago, by a pupil of the age of 13, whose mathematical

It was only after he had given his pupils a thorough grounding in algebraic and analytic operations and manipulations, and when they were fully cognisant of the meaning and significance of limits when dealing with infinite series, that De Morgan initiated them into the subject of the differential calculus. Initially this would involve imparting the basic rules and giving examples; for instance, one of the tracts features pages of functions and their derivatives (e.g. $\phi x = a^x$, $\phi'x = a^x \log a$) to be committed to memory. Following this, subjects such as the product, quotient and chain rules, explicit and implicit differentiation, and maxima and minima would be covered. Since the calculus was a far from elementary subject, we can be sure that a fair number of De Morgan's students would have encountered problems. Indeed, from one of the tracts we can tell that a particular difficulty concerned the differential coefficient of a function of a function - a problem still encountered by students today.

A beginner sees $(1+x^2)^3$, and remembering that x^3 gave $3x^2$, he writes down $3(1+x^2)^2$. He ought to have written $3(1+x^2)^2 \times 2x$. The truth is that he has correctly answered *a question*, - but not *the question which was asked*.¹²⁸

Due either to lack of time or, as was probably the case, a need to ensure that the class was fully comfortable with the methods of the differential calculus, De Morgan's initial teaching of integration proceeded no further than finding areas under curves. However, there is also evidence that he began elementary instruction on differential equations in this class, although this involved little more than defining basic notions such as the order of an equation, the integrating factor, and how to find general and singular solutions. Such an introduction would have been of very little use to those who chose to end their mathematical studies at this point. But these final subjects were not introduced for their benefit: they were to provide a background for the detailed course of study reserved for students who proceeded to De Morgan's higher senior class.

power was singularly in advance of his years. Of many things as worthy of remark in one so young, I only remember what is here given. Time and thought have developed this boy into Professor Sylvester, whose inventive power, in everything to which his taste has led him, places him in the highest rank." Once again, it seems, the teacher was not slow to learn from his pupils.

¹²⁸ ULL, MS. 775/197, f.17.

4.2.5 The Higher Senior Class

Attending De Morgan's lectures as far as his lower senior class would have been perfectly adequate to equip the average student with enough mathematical knowledge to enable him to pass the B.A. examination at the University of London, as well as to move on to the study of natural philosophy in the college. However, for those exceptionally capable (and keen) students who wished to submit to examination for honours, and perhaps later a masters degree, it was advisable to enter University College's highest mathematical class, where De Morgan would instruct them in the most advanced areas of their subject. This course was obviously the most technically demanding and, despite the fact that the class would never have been huge, one to which De Morgan clearly devoted much time and attention.

This is evinced by the number of notebooks he wrote for this class, which number 138, more than for any other division of his students. Of course, given the advanced nature of the subjects he was treating, this high number of tracts is also explained by the fact that fewer, if any, elementary textbooks were available on the topics of his higher senior lectures. For much of this section of the course, the most useful work would have been his *Differential and Integral Calculus*, since the subject, in all its many forms and applications, dominated the material covered. Other areas were also treated, such as further theory of equations, three-dimensional geometry and probability theory, but, as far as the existing tracts are concerned, their study was vastly outweighed by the amount of time devoted to calculus-related topics.

Chief among these was the study of differential equations, briefly introduced in the lower senior class. As with all De Morgan's tracts on subjects of some complexity, those dealing with the first principles cover each aspect in careful detail, from the first formation of linear and then higher order equations, to finding particular and general solutions, covering cases of failure of certain types, and eventually reaching partial differential equations. It is quite obvious from the sheer number of notebooks relating to the various types of equation (around thirty) that De Morgan was anxious that his students should obtain as much experience and practice of solving them as possible. He even wrote an entire tract containing model solutions to questions on the subject from University of London examination papers. The following example illustrates the typical level of such problems:¹²⁹

¹²⁹ ULL, MS. 775/247, f.5.

$$y'' - 4y' - 4y = x^2$$

There will be a particular solution of the second degree.

Let it be

$$y = ax^2 + bx + c$$

$$y' = 2ax + b$$

$$y'' = 2a$$

$$y'' - 4y' - 4y = 2a - 4b - 4c - (8a + 4b)x - 4ax^2$$

$$-4a = 1, \quad a = -\frac{1}{4},$$

$$8a + 4b = 0, \quad b = \frac{1}{2},$$

$$c = \frac{a}{2} - b = -\frac{5}{8}$$

$$y = -\frac{x^2}{4} + \frac{x}{2} - \frac{5}{8} + \text{solution of } (y'' - 4y' - 4y = 0)$$

$$k^2 + 4k - 4 = 0 \text{ gives } k = -2 \pm \sqrt{8} = 2(-1 \pm \sqrt{2})$$

$$y = -\frac{x^2}{4} + \frac{x}{2} - \frac{5}{8} + A\epsilon^{2(-1+\sqrt{2})x} + B\epsilon^{2(-1-\sqrt{2})x}.$$

The chief application of differential equations in De Morgan's higher senior was to the study of curves and surfaces. Typically, a whole tract is taken up with an introduction to the concept of curvature, which he defined as "the difference between the arc of a curve, and part of a straight line, or of the boundary of a polygon".¹³⁰ Succeeding tracts then continue the treatment to discuss, *inter alia*, uniform and non-uniform curvature of lines and surfaces, developable surfaces (i.e. surfaces that can be flattened out onto a plane) and surfaces of revolution. In these tracts, the subject matter is almost entirely based on Gaussian differential geometry, especially those concerning the measure of curvature, tract 47 containing the credit: "All that relates to the measure of curvature in this and the former tract is from Gauss' *Disquisitiones Generales circa Superficies Curvas*, 1827 - with the demonstration somewhat altered."¹³¹

The class was also introduced to a second form of differentiation in order to facilitate the subsequent study of mechanics. This was the calculus of variations, or the study of infinitely small variations independent of time, used to solve various problems of maxima and minima. In his first tract on the subject, De Morgan gave two examples to distinguish this variational calculus from the differential calculus previously used:

¹³⁰ ULL, MS. 775/130, f.1.

¹³¹ ULL, MS. 775/90, inside front cover.

1. In mechanics, ... dx represents an infinitely small length which actually will be described in the time dt ensuing next after the completion of t seconds from given epoch: while δx represents an imaginary displacement which never will take place, but which is made useful in calculating those which will.

2. When x is a function of t , and, without changing the value assigned to t , the character of the function undergoes an infinitely small alteration; thus giving an infinitely small alteration in the value of x , that of t remaining.¹³²

Much of the material contained in the tracts is also presented in his *Differential and Integral Calculus*, such as the famous brachistochrone problem of finding "the curve of shortest descent from one curve to another, a heavy point descending upon the curve (supposed hard) by the action of gravity, with no velocity at the commencement".¹³³ Another is the following problem which, he tells us, "was solved by James Bernoulli, in the early days of the differential calculus".¹³⁴

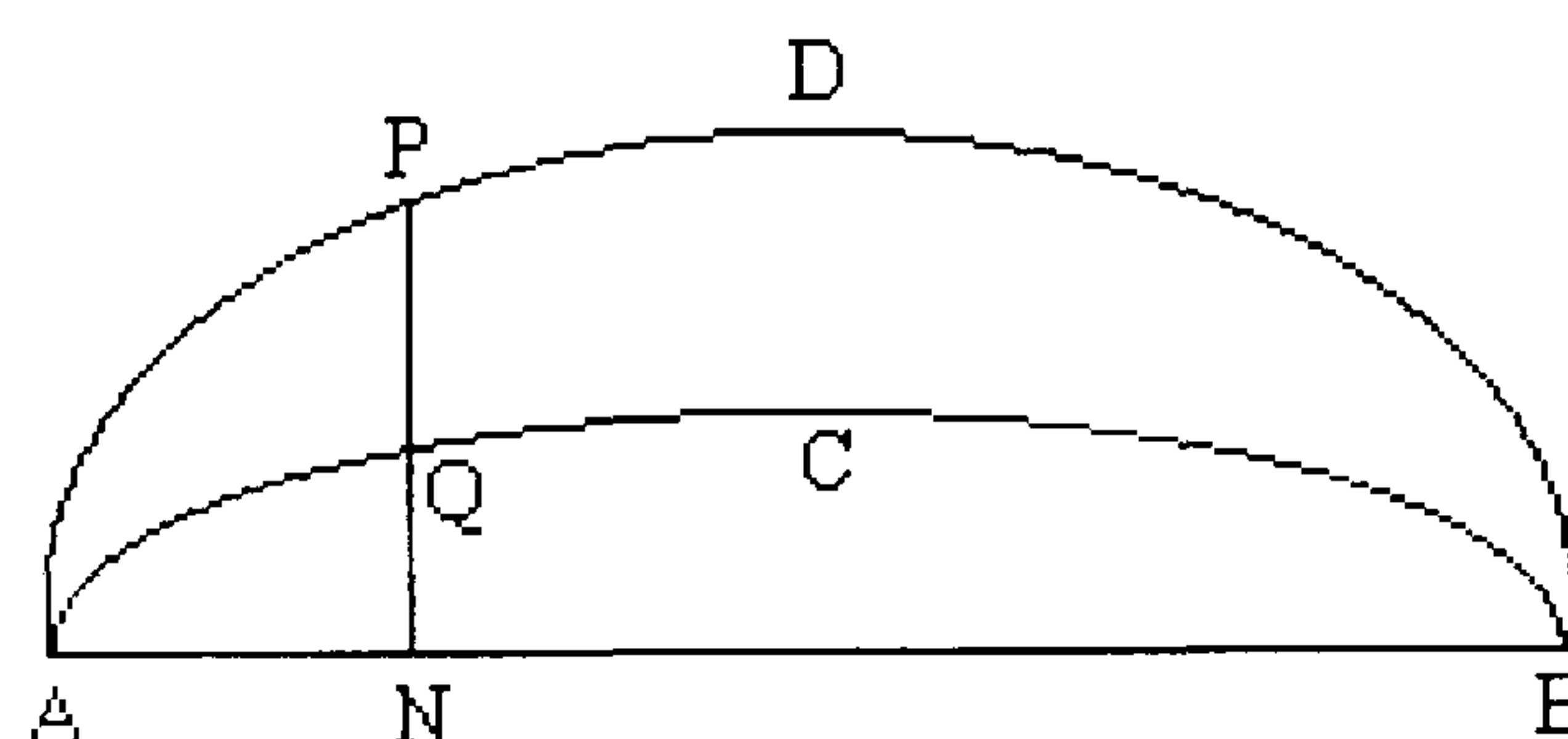


Figure 8

Required a curve ACB of given length, on a given chord AB, such that another curve ADB being described, of which the ordinate PN is a given function S of the arc AQ, the area APB shall be a maximum or a minimum.¹³⁵

De Morgan's textbook also features the full solution to this problem.¹³⁶

Other techniques with which the higher seniors would also have been acquainted were the calculus of finite differences and the calculus of functions, on which subject De Morgan had written a book-length article for the *Encyclopædia Metropolitana* in 1836. The latter more algebraic method was also employed in his treatment of infinite series in this class,

¹³² ULL, MS. 775/185, ff.1-2.

¹³³ ULL, MS. 775/186, f.4.

¹³⁴ A. De Morgan, *op. cit.*, (100), 467.

¹³⁵ ULL, MS. 775/187, f.7.

¹³⁶ A. De Morgan, *op. cit.*, (100), 467-8.

where results such as Taylor's and Maclaurin's theorems, previously established by him at the lower senior level, were developed to consider extensions such as Laplace's and Lagrange's theorems, i.e., respectively,

$$\Psi y = \Psi Fz + \phi Fz \cdot \overline{\Psi Fz}' \cdot x + \frac{d}{dz} \{ \overline{\phi Fz}^2 \overline{\Psi Fz}' \} \cdot \frac{x^2}{2} + \dots \quad (\text{where } y = F(z + x\phi y))$$

and

$$\phi y = \phi z + \frac{1}{2} \frac{d \overline{\phi z}^2}{dz} \cdot x + \frac{1}{3} \frac{d^2 \overline{\phi z}^3}{dz^2} \cdot \frac{x^2}{2} + \frac{1}{4} \frac{d^3 \overline{\phi z}^4}{dz^3} \cdot \frac{x^3}{2 \cdot 3} + \dots, \text{ which follows if } Fz = z.$$

No doubt influenced by Cauchy's recent work on analysis, De Morgan also introduced his students to the limitations of these theorems, urging them to be wary of placing too much faith in series expansions without due consideration:

...the mere statement of a series, independently of the method by which it is obtained, is no more a definite statement than the form $\frac{0}{0}$. Undoubtedly series in general are only produced, in our way of arriving at them, out of one form only: and the appearance of $1 + x + x^2 + x^3 + \dots$ *ad infinitum* ($x < 1$), given as the result of a question by a mathematician of this planet and century, is very good presumption that $\frac{1}{1-x}$ is the true answer to the problem: because we know that his applications of mathematics almost always deal with functions which *admit of total development by Maclaurin's Theorem*. And assuredly $\frac{1}{1-x}$ is the only *such* function which can give $1 + x + x^2 + x^3 + \dots$. But if $1 + x + x^2 + x^3 + \dots$ should have been obtained in some way which presented it as $(1 + 0) + (x + 0) + (x^2 + 0) + (x^3 + 0) + \dots$ then, whether this be seen, or only implied in process, the result derived from the series cannot be trusted. For [example], ... the development of $\frac{1}{1-x} + \phi x \cdot \epsilon^{-\frac{1}{x^2}}$, ϕx being any ordinary function, is $1 + 0 + (x + 0) + (x^2 + 0) + \dots$ ¹³⁷

In addition to the study of these 'pure' mathematical subjects, De Morgan also managed to include a few items of applied mathematics. Indeed, more attention was devoted to the consideration of mathematical applications in the higher senior class than in any other - although the proportion of overall time spent on them was still minute. One subject considered was probability theory, which the students would have studied - in its pure form - since the higher junior class. De Morgan would now begin to introduce them to its

¹³⁷ ULL, MS. 775/289, ff.16-17.

applications, most notably its use in error theory, a precursor of what would now be called mathematical statistics. Briefly stated, it assumes that in good observational experiments, any errors will be very small, so that one can be certain that all results will be contained within a boundary of, say, $\pm E$. Then, in De Morgan's words:

Let the law of probability of error be expressed by there being the chance $\varphi x \cdot dx$ that, in an observation about to be made, the error shall be between x and $x + dx$. Then, to express the above certainty, we have

$$\int_{-E}^E \varphi x \, dx = 1. \text{ }^{138}$$

As with much of the material in his higher senior class, De Morgan's teaching of the theory of errors of observation was heavily influenced by the work of Gauss a few decades before. This is hardly surprising since it was Gauss's computation of the orbit of the asteroid Ceres in 1801 which had laid the foundations of the subject in the first place. Moreover, the main topics covered by De Morgan's tracts in this area, such as the weight of observations and the method of least squares, were all introduced by Gauss in his *Theoria motus corporum celestium* (1809) and *Theoria combinationis observationum erroribus minimis obnoxia* (1823). Thus once again, although the research was not his own,¹³⁹ De Morgan can be seen to be acquainting his students with (fairly) recent work on a new and rapidly growing area of mathematical research.

Less recent - but certainly still applied - mathematics is contained in two notebooks on the subject of dynamics. Strictly speaking, this would have been taught by the professor of natural philosophy, but De Morgan's treatment was entirely mathematical, dealing purely with theoretical problems involving the derivation of equations of motion for particles travelling under certain conditions. Moreover, throughout these tracts, he is at pains to stress the distinction between the abstract mathematical notions of velocity and acceleration on the one hand, and the physical phenomena (e.g. force, pressure and attraction) which cause them. Thus, for example:

When, as is usual in books on mechanics, *acceleration* is much confounded with *force measured by the acceleration it produces*...- called *accelerating force* - the *centrifugal acceleration*, a law of space, gets the

¹³⁸ ULL, MS. 775/19, f.2.

¹³⁹ Although one of the later tracts does contain his paper 'On the theory of errors of observation', *Transactions of the Cambridge Philosophical Society*, **10** (1861), 409-427.

name of *centrifugal force*, whether there be such a force in action or not.¹⁴⁰

His motivation for thus trespassing on material within the domain of mathematical physics was his belief that "the want of sufficient attention to this distinction puts some difficulties in the way of beginners in dynamics".¹⁴¹ In other words, he thought that if his students received an adequate notion of velocity and acceleration independently of any physical consideration of the properties of matter, they would be better equipped to understand the subject of dynamics when they came to study natural philosophy. This, after completing the full mathematics course under De Morgan, they would have been more than capable of doing.

In fact, viewing the surviving mathematical tracts as representative of De Morgan's entire syllabus, one is impressed not just by the level to which mathematics was taught, but also by the range of topics to which the students were exposed by their professor. To be sure, there is nothing unusual in his basic course structure, whereby the subject is developed from arithmetic and Euclid through the standard branches of algebra, geometry, trigonometry and calculus; but this is hardly an original feature. Rather, it is the additional, less prominent topics, absent from the course outlines and found only in the tracts, which give the course its variety and make it particularly distinctive. The result is a mathematical course of considerable scope and breadth.

We have already drawn attention to his consideration (albeit brief) of more minor areas such as topology and projective mapping, but other mathematical sidelines were also pursued. In particular, we should also mention a tract on the "Mathematical Theory of the Musical Scale", designed for the lower senior class. This is an introduction to the mathematics (mostly depending on arithmetical ratio and proportion) of musical ideas such as pitch, tone and scale. Another good example of a mathematical application, this is a very idiosyncratic choice of topic to which no clue is provided as to the reason for its inclusion. We can only conclude that De Morgan was trying to acquaint his students with as many mathematical topics as possible.

De Morgan's course was as advanced as it was varied. Indeed, it extended almost as far as an undergraduate course could at the time, since developments in many branches

¹⁴⁰ ULL, MS. 775/297, f.16.

¹⁴¹ *ibid*, inside front cover.

(especially analysis and algebra) were transforming the subject almost as it was being taught. This is reflected in the fact that the tracts were constantly being updated. A good example is found in notebooks relating to the theory of equations, one of the most rapidly-expanding areas at this time, which yielded new subjects not only in the form of complex analysis (see above), but also group theory. Although never taught by De Morgan, many of the results which contributed to this latter development are contained in a tract written in 1855, featuring "selections from what has been recently done in the higher parts of the theory of equations".¹⁴² This featured substantial extracts from the second edition of Serret's *Cours d'algèbre supérieure* (1854), the third edition of which, published in 1866, was to mark the first appearance of Galois theory in a textbook.

Having been given a thorough grounding in most areas of contemporary mathematical science, even proceeding far enough in certain areas to have become acquainted with several aspects of recent research, the student would have several options for further study. Although the concept of a postgraduate research student did not really exist, the higher senior class would almost certainly have served as a good starting point for those aspiring for an academic career in mathematics, since it not only provided guidance for those aiming for mathematical honours, but also those trying for an M.A. or preparing to embark on a further course of study at Cambridge. But, however far the student's mathematical studies had progressed, they were never pursued in isolation, being usually accompanied, or at least succeeded, by a course in natural philosophy. Accordingly, we now proceed to a discussion of the work of De Morgan's colleagues in that chair during the period 1836-67.

4.3 Natural Philosophy at UCL

While mathematical students had the luxury of a professor who supplied copious volumes of handwritten notes for their use, no such service was provided by any of the occupants of University College's chair of natural philosophy. Indeed, as with De Morgan's teaching between 1828 and 1831, we are forced once again to rely solely on official prospectuses and examination papers for our information as to the content of their respective courses. For this reason, our knowledge of their mathematical composition is understandably more sketchy than for the contemporaneous syllabus of De Morgan; but this is perhaps

¹⁴² ULL, MS. 775/244, f.1.

inevitable since, in the study of natural philosophy, mathematics was just one component of a much wider course. As mentioned in section 2.1.2, from its foundation, the chair of natural philosophy encompassed the subjects of experimental physics and what would now be called applied mathematics, although, as we shall see, for much of this period, the latter subject was not a major concern.

Therefore, in addition to a summary of the mathematics taught within the programme of natural philosophy during these years, this section will also provide an account of the various professors who were engaged in its tuition. During the thirty years following De Morgan's return to the college, there were no fewer than five different professors of natural philosophy at University College, each with vastly contrasting personalities and manners of teaching their subject. In 1836, the chair was held by the Rev. William Ritchie (1790-1837), who had succeeded Dionysius Lardner in 1832. Although a perfectly capable mathematician, Ritchie was primarily an experimental physicist; so, while his lecture course laid much emphasis on statics, dynamics and hydrostatics, as well as optics, heat and astronomy, these topics were treated far more practically than theoretically. Sadly, his tenure of the professorship was cut short by his sudden death after a short illness in September 1837, less than a year after De Morgan's return.¹⁴³

4.3.1 The Jewish professor

In the autumn of the previous year, the professor of mathematics had died within weeks of the start of the academic session; the college now found itself in a similar position with regard to the chair of natural philosophy. Consequently, the post was hurriedly advertised, in response to which six applications were received and a committee of the college's senate, chaired by De Morgan, appointed to select the new professor. While the committee's report shows its members to have been largely unimpressed with the majority of the candidates, it is clear that one applicant stood out from the rest by virtue not only of an imposing set of testimonials, but also the substantial impression he had previously made upon the chairman when he had attended his mathematical classes nine years previously. This was De Morgan's outstanding former student, James Joseph Sylvester.

Following his premature departure from the college in 1829, Sylvester had transferred to the school attached to Liverpool's Royal Institution, before entering St. John's College, Cambridge in 1831, aged seventeen. In January 1837, he had taken the place of second

¹⁴³ UCL College Correspondence, No. 4109, C. Duncan to Robert Liston, 15 Sept. [1837].

wrangler in the Tripos,¹⁴⁴ although the University's religious tests prevented him from obtaining his degree and staying on at Cambridge. The following October, on becoming aware of the vacancy of the natural philosophy professorship at University College, he applied for the position, enclosing twenty-two testimonials of character and mathematical ability. Due to his age, his non-Anglican beliefs, and the fact that he was only recently down from Cambridge, comparisons may obviously be drawn between the application of the young Sylvester and that of his former professor exactly a decade earlier. This similarity is furthered by extracts from some of his references, which are distinctly reminiscent of earlier comments made by De Morgan's tutors.

To an even greater extent than De Morgan's testimonials of 1828, Sylvester's references are characterised not only by their solid endorsements of his academic suitability but also by the calibre of the mathematicians who provided them. For example, George Peacock wrote of "the very high opinion which I entertain of his very superior abilities. I have seen one of his memoirs, which shows him to be a first rate analyst, and the report which was given by all those examiners for the Mathematical Tripos in January last, of whom I have made the inquiry, completely confirms the opinion which I have expressed respecting him."¹⁴⁵ Philip Kelland similarly declared Sylvester's mathematical acquirements to be of the highest order, adding "that I have found in Mr. Sylvester a facility in expressing his ideas, and of rendering intelligible even subjects the most abstruse. From long acquaintance with Mr. Sylvester, I am bound to express my entire conviction that his moral character is perfectly unexceptionable."¹⁴⁶

But it is the testimonial provided by Olinthus Gregory, from the Royal Military Academy in Woolwich, which is at once the most lengthy, enthusiastic, and candid:

I have known Mr. Sylvester from his boyhood, and though from various circumstances our intercourse has only been of an interrupted character, yet I have traced the development of his intellectual and scientific faculties with peculiar interest. I regard Mr. Sylvester as a gentleman of great and original genius in reference to the abstruse sciences; and of a rich and ready invention with regard to mathematical theories, to practical expedients and philosophical application. ... I ought in fairness to say that I believe he has not, as yet, had any experience as a public *lecturer*; but that

¹⁴⁴ John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 6, 100.

¹⁴⁵ University College London Archives, *Mr. J. J. Sylvester's Testimonials*, printed booklet enclosed with letter from Sylvester to Lord Brougham, (Brougham Correspondence, No. 17,047), 22 Nov. 1837, p.5.

¹⁴⁶ *ibid*, 11.

as a private teacher of mathematics and mathematical philosophy in the University of Cambridge he has had much practice and a corresponding success.¹⁴⁷

The efforts of this final, and perhaps most influential, referee can also be said mirror those of John Philips Higman on behalf of De Morgan, since both men wrote an extra letter of recommendation in addition to their testimonial. This time, the recipient was Lord Brougham:

Royal Military Academy
Woolwich. 7 Nov 1837.

My dear Lord

I am sure you will pardon me for addressing to you a short letter, in reference to Mr. James Joseph Sylvester, who is a Candidate for the appointment of Professor of Natural Philosophy, at the University College, vacant by the death of Dr. Ritchie. I have given him a Testimonial to lay before the Council, which your Lordship may have seen already. Still I venture thus to write.

Mr. Sylvester was a student at University College some years ago; but was obliged to quit it, on account of some indiscretions. Mr. De Morgan I well recollect, thought very highly of his talents and genius, at that time; when, however, he was a mere rude, raw, boy. Since then he has studied at Cambridge with great assiduity and success: and in January last he distinguished himself very considerably in his public examination; standing, if I do not mistake, as Second or Third Wrangler. Being a *Jew*, he could not graduate; and the same circumstance precluded him from standing for Dr. Smith's Prize. I learn from various of my Cambridge friends, that he is highly appreciated there, on account of his genius and his scientific attainments. And this, I take for granted, will be evinced by the character of his testimonials from that University.

My main, indeed my *only*, fear respecting his entire suitability, grows out of the consideration of his age. Yet I cannot but recommend him to your Lordship's consideration; and, if you would indulge him with an audience of half an hour, and personally investigate his qualifications, I am persuaded you would think *very* favourably of him; whether you should regard him as precisely qualified for the Professorship, or not. The circumstance of his being a Jew, cuts him off from all prospect of advancement in any other British Collegiate Institution, than that over which your Lordship presides. *That* circumstance will, I am sure, excite all your liberal and generous sympathies in his favour; whether you approve of his appointment, on the present occasion, or not.

¹⁴⁷ *ibid*, 22.

...I hope your Lordship is enjoying a perfect restoration of health;
and begging you will forgive me for this intrusion, I have the honour to be,

My dear Lord,

Your Lordship's obliged

and faithful Servant,

Olinthus Gregory.¹⁴⁸

Ironically, by virtue of the sheer mass of testimonials in his favour, this letter would probably have been superfluous in the matter of selecting the new professor, since the committee (of which Brougham was not a member) were already convinced of the desirability of Sylvester's appointment. However, they did feel the need to reassure the college council that no repetition of the cause of his previous departure was likely to arise from the same temperament. To do this, they drew attention to his time at St. John's College, "which is remarkably strict in requiring propriety of behaviour; so much so, that, justly or not, an impression prevails that great regularity and attention to the rules of college discipline count nearly as much as talent in obtaining scholarships and fellowships. His college testimonial, which embraces the period from 1831 to 1837, owing to interruptions from illness, states that he has behaved soberly and regularly: and the Committee attribute considerable importance to this proof that, since the period above alluded to, Mr. Sylvester has acquired and exercised self-control."¹⁴⁹

In addition to this they expressed their opinion that, despite his lack of experience in teaching natural philosophy, "a properly qualified mathematician possessing fluency of delivery (which Mr. Sylvester is known to several of the Committee to possess) will speedily become fully competent to all the duties of the chair".¹⁵⁰ In any case, they argued that, irrespective of teaching ability, it was highly desirable to secure "the services of those who are likely to advance, as well as to diffuse, the knowledge of their subject...and it could easily be shown that there has been more than one person who has left his name inseparably connected with the history of discovery, who had not, at the same age, given such decided proof of his power as appears to have been exhibited by Mr. Sylvester".¹⁵¹ The weight of these arguments in his favour, from a committee chaired by one of his

¹⁴⁸ University College London Archives: Brougham Correspondence, No. 20,220, Olinthus Gregory to Lord Brougham, 7 Nov. 1837.

¹⁴⁹ UCC, No. AM/7, Committee Report on the appointment to the chair of natural philosophy, 18 Nov. 1837, f.4.

¹⁵⁰ *ibid*, f.5.

¹⁵¹ *ibid*, ff.5-6.

strongest advocates, ensured Sylvester's prompt election to the professorship and a swift return to his former college.

Unfortunately, he did not find his first academic appointment as rewarding as he would no doubt have wished. This was probably exacerbated by his shortcomings as a lecturer, since - despite the assurances of De Morgan's committee - he was by no means a clear expositor. In fact, as De Morgan admitted nearly thirty years later: "When he was with us he was an entire failure: whether in lecture room or in private exposition, he could not keep his train of ideas in hand."¹⁵² Moreover, he soon found that he did not particularly enjoy teaching natural philosophy, especially the experimental side. In particular, he had great difficulty drawing diagrams to illustrate his lectures, which even lessons from the school's drawing master did not ameliorate. Never being particularly dextrous manually (his handwriting was appalling), Sylvester avoided the use of instruments when he could, deliberately keeping his course as mathematical as possible.

The students who attended Sylvester's University College lectures experienced natural philosophy as applied mathematics in the Cambridge sense. Topics covered included statics, dynamics, hydrostatics, elliptic motion, gravitation, optics and astronomy, with little or no reference to heat, electricity, or magnetism. Illustration of how mathematically-inclined Sylvester's three-year course was can be gleaned from its prerequisites. For entry into the first year, students were required to have a knowledge of algebraic notation, proportion, and trigonometric functions. A familiarity with conic sections, quadratic equations, and spherical trigonometry was necessary to proceed to the second year; and for the third year, the student needed analytical geometry and the differential and integral calculus.¹⁵³

Despite the intellectual freedom offered by University College and the support and goodwill of the other professors, especially De Morgan, Sylvester became increasingly restless and dissatisfied with having to teach applied mathematics, longing for a pure mathematics chair of his own. The opportunity came in 1841 when the chair of mathematics at the University of Virginia (where two of his colleagues, George Long and Thomas Hewitt Key, had previously held professorships) fell vacant. Sylvester applied

¹⁵² University College London Archives: London Mathematical Society Papers, De Morgan to Thomas Archer Hirst, 29 June 1865.

¹⁵³ *University College, London. Session 1839-40. Faculty of Arts and Laws*, (London: Richard and John E. Taylor, 1839), 8.

and sought references from his fellow professors. Needless to say, De Morgan's testimonial, on behalf of the college senate, bore ample testimony to the high esteem in which the young professor was held by his former teacher:

No person of his years in this Country has more reputation than Mr Sylvester as an original Mathematician, or bids fairer to extend the exact sciences by his labours. From my own knowledge of what he has done, I can most safely say that he is a mathematician of great power well acquainted with the most modern of the science, & very zealous in the prosecution of his inquiries. By these qualifications he will certainly make his name well known as an original cultivator of mathematics to the credit of any institution [to which] he may be connected.¹⁵⁴

Sylvester's application was successful and he resigned his professorship at University College in August 1841, although not without some regret. After all, he was relinquishing his place at an institution "endeared to me by many private ties of regard",¹⁵⁵ and his letter of resignation closes with the assurance that "I shall ever continue to watch its progress towards consummating its strength with as much interest and earnest good will as if still enjoying the distinction of being ranked among its professors."¹⁵⁶ He left for his new position as soon as his duties in London were completed. Yet, despite his high hopes for his new position, all did not go well in America, and the next decade was to see Sylvester back as a teacher of mathematics in London, as chapter 7 will reveal.

4.3.2 The incompetent professors

Sylvester's successor in the natural philosophy chair was Richard Potter (1799-1886). Initially a Manchester corn merchant, Potter had developed an amateur interest in experimental science and began to write papers, one of which, on metallic mirrors, was published in David Brewster's *Edinburgh Journal of Science* in 1830.¹⁵⁷ Being encouraged to take his studies further, he entered Queens' College, Cambridge, where he studied medicine as well as mathematics, graduating as sixth wrangler in 1838.¹⁵⁸ After his election to a fellowship at Queens' the following year, he had devoted himself "to private tuition and to the continuation of a course of experimental investigation in natural

¹⁵⁴ UCC, Testimonial from De Morgan, [May 1841].

¹⁵⁵ *ibid*, James Joseph Sylvester to Charles C. Atkinson, 17 Aug. 1841.

¹⁵⁶ *ibid*.

¹⁵⁷ *D.N.B.*, 46, 219.

¹⁵⁸ Venn, *op. cit.*, (144), 5, 167.

philosophy",¹⁵⁹ the results of which appeared as papers in the *Transactions of the Cambridge Philosophical Society* and the *Philosophical Magazine*. It was presumably, at least partially, on the basis of these works that he was elected to the professorship at University College.

However, little more than a year after his arrival in London, the council were notified of his decision to leave England after Easter (1843) to take the chair of mathematics at the recently-established King's College, Toronto. The cause of this decision, not surprisingly, was the prospect of greater remuneration at the Canadian institution since, as he told the council, "from the uniform kindness and politeness which I have met with, from every one connected with the College, I assure you..., that nothing but pecuniary circumstances would have induced me to leave it".¹⁶⁰ In the mean time, to ensure that his lecture course for the 1842-43 session was completed, he arranged for a substitute to perform his duties for him. This was his friend Philip Kelland, whom he had met in Cambridge, and who travelled down from Edinburgh to deliver the required lectures between April and June 1843,¹⁶¹ receiving £84 16s 3d for his trouble.¹⁶²

In the meantime, the chair was once again re-advertised, being eventually filled by Charles Brooke (1804-1879), the 23rd wrangler of 1827 (De Morgan's year) who for the majority of the intervening years had been primarily occupied with the study of medicine.¹⁶³ Indeed, he claimed "a greater competency in applying the principles of Physics to Physiology & Pathology",¹⁶⁴ having lectured on natural philosophy at the Westminster Hospital School for the previous two years. Nevertheless, his authorship of at least one mathematical work¹⁶⁵ plus his contemporary reputation as a competent experimental scientist managed to secure him the professorship - although the conspicuous dearth of information regarding rival candidates perhaps provides another clue to his election.

¹⁵⁹ UCC, Richard Potter to Council, 7 Oct. 1841.

¹⁶⁰ *ibid*, Richard Potter to Council, 1 Nov. 1842.

¹⁶¹ *University College, London. Proceedings at the Annual General Meeting of Members of the College, 22nd February, 1843*, (London: Richard and John E. Taylor, 1843), 6.

¹⁶² UCC, Philip Kelland to Charles Atkinson, 17 March 1843.

¹⁶³ Venn, *op. cit.*, (143), 1, 394.

¹⁶⁴ UCC, Charles Brooke to Council, 15 May 1843.

¹⁶⁵ Charles Brooke, *A Synopsis of the Principal Formulæ and Results of Pure Mathematics*, (Cambridge: J. and J. J. Deighton, 1829).

Given the fact that Brooke does not appear to have been an ideal choice for the situation, it is perhaps not surprising that problems soon arose. Within a few weeks of the commencement of his duties, the council received the following memorandum:

University College
Nov 13. 1843

Sir

We, the undersigned, members of the Senior Mathematical class of Natural Philosophy in University College, beg respectfully to inform you, that we have been the *painful witnesses* of Professor Brooke's *confessed* neglect of the *higher* parts of analysis, during a period of 14 or 15 years, in favor of other professional engagements.

And whilst we record our warmest testimony to his high gentlemanly feeling, the extreme kindness of his manner, and the unabating interest which he has shown himself willing to take in our welfare, we find it *impossible* to make *any progress* under his tuition.

With these feelings and considerations we have arrived at the *mildest determination*, which repeated and mature deliberation has afforded us, that of silently but unanimously withdrawing ourselves from the lecture room.

Our object in thus addressing *you*, is respectfully to inquire what compensation for the fees, the Council may in its decision be pleased to allow us: and waiting your reply at the earliest possibility and convenience.

We have Sir the honor to be
Yours truly

Charles Howard
Richard Holt Hutton
Josiah Rees
Henry Robert Reynolds - The whole of the Senior Class
Moh^d. Tahir
I. W. Waley

P.S. We would request the transmission of this communication to Professor Brooke, *before* it is presented to the Council.¹⁶⁶

The chief objection of these students, then, was that "to all appearance, Mr. Brooke could only read from a book, and that they learnt no more from him than was in the book".¹⁶⁷ This charge of incompetence against a professor immediately recalls the unpleasant Pattison controversy which, it will be remembered, had serious repercussions both on the college and its staff in the early 1830s. However, the situation in 1843 was

¹⁶⁶ UCC, Student memorandum to Charles Atkinson, 13 Nov. 1843.

¹⁶⁷ *ibid*, De Morgan to Charles Atkinson, 16 Nov. 1843.

quite different. A re-enactment of the events of 1831 was forestalled by several circumstances, including the fact that Brooke's students were far less belligerent and far fewer in number than Pattison's had been. The principal difference, however, was that this time the offending professor candidly acknowledged the cause of the students' dissatisfaction. This admission was contained in a letter to the council written five days after the above remonstrance:

My Lords & Gentlemen

Since the commencement of my duty of instructing the Senior Mathematical Classes, I have become most painfully convinced of the fact, that altho' well acquainted with the whole range of Analysis, at the time of Publication of the Work lately submitted to you, many of the details of those branches of the science which have been disused by me, have escaped my recollection: a fact of which I was not aware, until I commenced putting my knowledge to the practical test, in instructing a Class.

In ignorance of the exact state of my recollection of the higher Analysis, I unfortunately undertook the duty of instructing an extra Class in all the higher branches of Physical Astronomy (which, as consisting of *only one* Pupil, I might, after the usages of the College, have declined) and the incessant efforts I was compelled to make to recover my lost ground with sufficient rapidity to satisfy the demands of both the senior Classes prevented my doing justice to either, & the consequence has been the remonstrance now before you.

I have conferred with Prof. De Morgan as to what immediate step would be most conducive to the welfare of the Class, & he has expressed himself willing to instruct them for this year, should they think fit to request his performance of that duty.

I must in justice to myself add my belief that in the other departments, my College duties have been satisfactorily performed. I have received some verbal expressions of approval of my Experimental course; & I enclose a note received a fortnight since, which I take merely as a favorable expression of an individual opinion in the Junior Mathematical department.

Should the plan I have suggested meet your views, I unhesitatingly pledge myself to resign the Chair, in sufficient time for another appointment to be made before the commencement of the next session, should I find myself unable in the intervening time *entirely* to recover my knowledge of the higher Analysis; & I may further add that I am perfectly willing to leave the question of comparative emolument, as between Prof. De Morgan & myself, entirely in your hands.

I have the honor to be,

My Lords & Gentlemen

Nov 18/43.

Your most obed^t Serv^t.
Chas. Brooke¹⁶⁸

Brooke's good-natured confession placed the college in a very embarrassing position. Should a professor be allowed to appoint a substitute to teach his classes while he concentrated on learning what he should have been teaching? The college senate ruled decisively in the negative, judging that such a course of action would have an injurious effect on the college's academic reputation. In any case, they pointed out, it would be unrealistic to believe that Professor Brooke could adequately master such a demanding subject after such a long absence from its study, especially since "The very mathematics themselves, as applied to physics, have undergone no small change in the last fifteen years".¹⁶⁹ In view of this, they reported to the council "our decided and unanimous opinion that Mr. Brooke should be recommended to retire from the Professorship of Natural Philosophy".¹⁷⁰

This resignation was immediately forthcoming,¹⁷¹ although Brooke requested - and was granted - leave to continue to teach his experimental classes, in which his ability had never been in question. Meanwhile, for the remainder of the session, in addition to his own classes, De Morgan gave extra tuition to the mathematical section of the natural philosophy course.¹⁷² In gratitude for his time and effort, his additional students "at the end of the session presented to him a handsome copy of Wilkinson's *Ancient Egyptians*".¹⁷³ Charles Brooke left the college after his lecturing duties were completed, and, despite this somewhat ignominious episode in his career, went on to achieve a distinguished reputation as a scientific author and inventor.¹⁷⁴ In the meantime, however, the council were faced, once again, with the task of finding a new professor.

In this they were further assisted by their professor of mathematics who, in a series of transatlantic communications with Richard Potter, proceeded to engineer the return of the college's erstwhile natural philosophy professor. De Morgan had discovered that Potter was far from happy in Canada, having been forced to settle for a lower income than he

¹⁶⁸ *ibid*, Charles Brooke to Council, 18 Nov. 1843.

¹⁶⁹ *ibid*, No. AM/33, Report on the State of the Class of Natural Philosophy, [25 Nov. 1843], f.8.

¹⁷⁰ *ibid*, f.12.

¹⁷¹ *ibid*, Charles Brooke to Council, 25 Nov. 1843.

¹⁷² *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1844*, (London: Richard and John E. Taylor, 1844), 6.

¹⁷³ S. E. De Morgan, *op. cit.*, (42), 120.

¹⁷⁴ *D.N.B.*, 6, 417-18.

had been promised. Moreover, the mathematics class in the Toronto college apparently contained "some as self-willed, idle, and ill-behaved youths as ever came into a Class room".¹⁷⁵ De Morgan therefore advised him "to put the matter into his hands, promising to obtain the best arrangement which the Council might think proper to accede to".¹⁷⁶ He then negotiated a settlement whereby the council guaranteed to endow the chair of natural philosophy with £150 per annum, in the hope that this measure would go some way to overcome the recurrent problem of retaining professors in that department.¹⁷⁷

This arrangement certainly produced the desired effect: Potter returned and was to remain at the college for over twenty years. During that time, he ran two courses on natural philosophy, experimental and mathematical, consisting of the following components:

Experimental & Descriptive Course:

1. Mechanics, comprising Statics, Dynamics, Hydrostatics, and Hydrodynamics. 2. Acoustics. 3. Optics, including the properties of ordinary and polarized light. 4. Electricity. 5. Astronomy.

Mathematical Course, Junior Class:

Prerequisites - Euclid 1-4, 6; elementary Algebra & Plane Trigonometry.

Content: Elementary Statics; Dynamics, as far as variable forces; Newton's Principia, sections 1-3; Elementary Hydrostatics; elementary Optics and the theory of optical instruments; Elementary Astronomy.

Mathematical Course, Senior Class:

Prerequisites - Geometry, Algebra, Trigonometry, Conic Sections, and elementary Differential Calculus.

Content: Analytical Statics; Dynamics, from variable forces; higher branches of Hydrostatics and Hydrodynamics; Optics; Plane Astronomy.¹⁷⁸

In contrast to the course previously taught by Sylvester, Potter's syllabus was far more elementary both in its prerequisites and the level of material covered. Also, unlike that of

¹⁷⁵ UCC, Richard Potter to Charles Atkinson, 25 June 1844.

¹⁷⁶ UCC, Philip Kelland to Charles Atkinson, 20 May 1844.

¹⁷⁷ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 26th February, 1845*, (London: Richard and John E. Taylor, 1845), 7.

¹⁷⁸ a) *The University College, London, Calendar for the Session 1853-4*, (London: Walton and Maberly, 1853), 8-9; b) *The University College, London, Calendar for the Session 1859-60*, (London: Walton and Maberly, 1859), 10-11; c) *The University College, London, Calendar for the Session 1864-65*, (London: Walton and Maberly, 1864), 19-20.

his predecessor (who was primarily a pure mathematician), Potter's course reflected his own research in experimental physics, his chief interests lying in that area, as is shown by his fifty-nine papers, chiefly in connection with optics. He also published a few textbooks on optics, hydrostatics, and mechanics, which were well respected at the time. However, unfortunately for his students, he turned out to be quite incompetent as a lecturer. According to Stanley Jevons (1835-1882), who attended his lectures in the early 1850s, his teaching was extremely dull.¹⁷⁹ Jevons' cousin, the chemist Henry Enfield Roscoe (1833-1915), was a student at University College a couple of years earlier. His description of Potter is, again, far from flattering:

The professor of Natural Philosophy was an extraordinary man - an enormous bulky body, with a face like a woman's and a piping voice. His method was that of the Cambridge of that day. His lectures were not experimental, and they were not appreciated by my fellow-students. He generally read from his own book on mechanics, holding it in his hand while he wrote up a formula on the blackboard, and occasionally would become confused, and would pipe out when a mistake was pointed out: "Reading and writing, gentlemen, reading and writing, make a mistake."¹⁸⁰

These defects in the professor's lecturing ability seem to have increased over time until, by the 1860s, his inadequacy as a teacher was notorious. Indeed, as another former student later recalled, by the end of his career, Potter had become a laughing-stock:

The Professor was the dearest of old gentlemen with long silky, silver grey hair, a winning smile, and a very gentle deprecatory manner.... But, as a teacher in my day, he had one fatal defect. He was worn out, he had lost his memory and not a few of his wits. In his experimental class he was mercilessly ragged. I have seen him snowballed in his lecture-room, I have seen him sprayed. His only retort was a deprecatory gesture which meant "How could you?"; and all he said was "Gentlemen, gentlemen." The apparatus was as worn out as the Professor. It never did what it was expected to do. Magnetic force, for example, would be demonstrated experimentally by holding a needle to what might once have been a magnet, but had ceased to attract, whilst the Professor said, "You see it wants a little helping, gentlemen." In his mathematical class the Professor was dependent upon his book. From his book he copied his problems on to his black board. Sometimes, ashamed of copying, he would attempt a few lines on his own, and get hopelessly involved. In despair he would

¹⁷⁹ Harriet Ann Jevons (ed.), *Letters and Journal of W. Stanley Jevons*, (London: Macmillan & Co., 1886), 35.

¹⁸⁰ Henry Enfield Roscoe, *The Life and Experiences of Sir Henry Enfield Roscoe*, (London: Macmillan & Co., 1906), 29.

return to his book and copy the conclusion at the bottom. Some unkind student would point out a *non sequitur* in the middle. The dear old man, with a puzzled look, would glance from the blackboard to his book and from his book to the blackboard, and then turn to his class with an air of triumph and say, "But, gentlemen, you see the conclusion is correct. It is a case of compensation of errors."¹⁸¹

Yet incompetence in the lecture room was not in itself considered an impediment to the adequate performance of a professor's duties. As long as the council and the senate were satisfied that the progress of the classes was satisfactory there was no question of dismissal. In any case, as far as can be determined, Potter does not appear to have been the object of any student complaints of the kind previously levelled at Charles Brooke, his inadequacies seeming to provoke more amusement than displeasure. We should also remember that, in the days before old-age pensions, professors - like everyone else - had to accumulate as much revenue as possible before retiring, and this often entailed working for longer than one was perhaps able. Such, it would seem, was the case with Richard Potter, who finally retired in 1865.

4.3.3 The Yorkshire doctor

The departure of Potter gave the college an opportunity to reform its teaching of natural philosophy, by dividing the professorship into two separate chairs - mathematical and experimental physics. This decision, by another committee chaired by De Morgan, was made for the principal reason that "the duties of the two chairs, though connected with one subject, demand decided differences of thought, reading, and talent: insomuch that it may happen, and does happen, that an individual of marked eminence in either may be below mediocrity in the other".¹⁸² To the professorship of experimental physics, the committee recommended the appointment of the physicist George Carey Foster (1835-1919), a former student of the college who had attended De Morgan's lectures in the early 1850s. He was to hold the chair¹⁸³ with much distinction until 1898.

Simultaneously, the professorship of mathematical physics was awarded to a mathematician of very high standing by the name of Thomas Archer Hirst (1830-1892). Hirst's primary area of research was geometry, for which he had gained a wide reputation, both nationally and internationally, by the time of his appointment. Yet, despite this

¹⁸¹ James Bourne Benson, "Some Recollections of University College in the Sixties", MS (1921), University College Archives, Materials for the history of UCL, Mem. 1B/3, f.1.

¹⁸² UCC, No. AM/103, Report on the Chairs of Natural Philosophy, 1865, f.1.

¹⁸³ Renamed simply Physics in 1867.

prestige, which was to increase as his career progressed, he is virtually unheard of today. In fact, his near-obscurity would be almost total had he not been in the habit of writing an extensive diary for a period of nearly half a century, from the summer of 1845 to his death in 1892. This journal, which is highly discursive in places, covers his life in the minutest detail and provides many details concerning life in mathematical and scientific circles of the mid-Victorian era which would otherwise be unknown.¹⁸⁴ A brief examination of Hirst's life and career with the aid of this valuable source will thus give an extra dimension to his mathematical background and how it was brought to bear on his teaching at University College.

Hirst was born into a middle-class family in the small town of Heckmondwike in Yorkshire on 22 April 1830. At the age of fifteen, he was apprenticed to a surveyor in Halifax, where he made the acquaintance of a young Irish engineer by the name of John Tyndall (1820-1893), who was to become his lifelong friend and a guiding influence on his intellectual development. Inspired by Tyndall's example, Hirst soon began an extensive programme of self improvement, concentrating especially on mathematics and the sciences, and eventually enrolling at the Halifax Mechanics Institute and Mutual Improvement Society in February 1848. By this time, Tyndall had left Halifax, and indeed England, to study chemistry at the University of Marburg in Germany; and, after completing his apprenticeship, Hirst followed him there in October 1850.¹⁸⁵

At Marburg, Hirst studied physics under Christian Gerling, mathematics with Friedrich Stegman, but was most impressed by the teaching of Robert Bunsen in chemistry. However, following Bunsen's departure from the university in 1851, it was his progress in mathematics from which he derived the most pleasure and satisfaction. In particular, he found himself especially drawn to the new continental methods of geometry. He began to concentrate on their study, preparing a Ph.D. dissertation entitled "Ueber conjugirte Diameter im dreiaxigen Ellipsoid" ("On conjugate diameters of the triaxial ellipsoid"). So intensive was his mathematical research that, by June 1852, this work was largely

¹⁸⁴ A typescript copy of the Hirst diaries is held at the Royal Institution in London. The diaries have been edited by W. H. Brock and R. M. MacLeod, and were published in microfiche by Mansell, London, in 1980.

¹⁸⁵ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant: I. A Yorkshire Surveyor, *American Mathematical Monthly*, **100** (1993), 435-441.

complete and the following month he was awarded his doctorate, having completed his studies in two years.¹⁸⁶

Following the completion of his Ph.D. thesis, Hirst decided to travel, journeying first to Göttingen, where he made the acquaintance of Wilhelm Weber (1804-1891) and Carl Friedrich Gauss (1777-1855), before travelling on to Berlin and attending the lectures of Lejeune Dirichlet (1805-1859) and Jakob Steiner (1796-1863).¹⁸⁷ Throughout the 1850s he travelled extensively around Europe, becoming well-acquainted with many of the foremost mathematicians of the time, such as Louis Poincot (1777-1859), Joseph Liouville (1809-1882) and Michel Chasles (1793-1880) in France, and Francesco Brioschi (1824-1897), Barnaba Tortolini (1808-1874) and Luigi Cremona (1830-1903) in Italy.¹⁸⁸ It should be remembered that, at this point in time, it was rare for a British mathematician to study abroad. Thus for such a person to travel widely around Europe forming contacts and friendships with many of the leading continental mathematical practitioners was quite exceptional. Consequently, Hirst was singularly well-connected with regard to both European mathematics and mathematicians, being far better informed about recent mathematical developments on the continent than many of his British contemporaries.

On his return to England in 1859, he was not slow in gaining an introduction to this section of the mathematical community, thanks to his friendship with Tyndall, who by now was firmly established in London scientific circles. For example, within weeks of his return, Hirst had been introduced to both Sylvester and Arthur Cayley (1821-1895) who were, by this time, rapidly achieving the status of the foremost pure mathematicians in Britain.¹⁸⁹ Both men would quickly become his good friends; indeed it was they who were partially responsible for proposing Hirst's name for a Fellowship of the Royal Society, to which he was elected in April 1861.¹⁹⁰ Meanwhile, his research continued, with the publication of a few papers on various matters relating to the geometry of

¹⁸⁶ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant: II. Student Days in Germany, *ibid*, 531-538.

¹⁸⁷ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant: III. Göttingen and Berlin, *ibid*, 619-625.

¹⁸⁸ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant: IV. Queenwood, France and Italy, *ibid*, 723-731.

¹⁸⁹ A role they undoubtedly shared with Henry John Stephen Smith (1826-1883), Savilian Professor of Geometry at Oxford from 1860 to 1883.

¹⁹⁰ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant: V. London in the 1860s, *op. cit.*, (185), 827-834.

surfaces in the *Philosophical Magazine* and Sylvester's recently-founded *Quarterly Journal of Pure and Applied Mathematics*.

Then as now, however, ability in a particular academic field was no guarantee of appropriate employment, and appointments for mathematicians were particularly scarce. Yet, fortunately for Hirst, a suitable position became vacant only a matter of months after his arrival in London, as he recorded in his diary:

4 March 1860: ... an important event has occurred causing a complete revolution in my former life. Prof. Williamson¹⁹¹ had inquired through Tyndall if I should be willing to undertake the Mathematical Tuition at University College School their present Master Cooke¹⁹² being disabled by illness. I replied in the affirmative and accordingly on Tuesday I received a letter from Prof. Key, Williamson's father-in-law and Principal of the School offering me the position. I called on him in the evening and it was arranged that I should commence work next morning Wednesday. Accordingly I was introduced by Key to my class on Wednesday morning at 9.15, and have continued to attend ever since.¹⁹³

As has been mentioned in section 3.2.3, due to the progressive methods of teaching employed, the standard of education offered at the school was extremely high. This is exemplified by the level of mathematics the pupils were engaged in studying on Hirst's arrival: "The highest class is engaged with the 6th book of Euclid, the binomial theorem in Algebra, De Moivre's theorem in Trigonometry and the simple machine in mechanics."¹⁹⁴ The following September, he was reporting his intention to "commence the lessons on Geometry according to the natural system (Lacroix or Legendre) with my youngest pupils and for the present they will be provided with French books on Geometry".¹⁹⁵ It is perhaps not surprising, therefore, that, in 1862, the school's mathematical prize "consisted of Lagrange's *Calcul des Fonctions* and *Mécanique Analytique* and Monge's *Géométrie Descriptive*".¹⁹⁶

¹⁹¹ Alexander Williamson (1824-1904), professor of chemistry at University College from 1849 to 1887.

¹⁹² Rev. William Cooke (c.1805-1860), of Trinity College, Cambridge, who was mathematics master at the school from 1838 until 1860.

¹⁹³ William H. Brock and Roy M. MacLeod (eds.), *Natural Knowledge in Social Context: The Journal of Thomas Archer Hirst, F.R.S.*, (London: Mansell, 1980), 1529.

¹⁹⁴ *ibid*, 1529-30.

¹⁹⁵ *ibid*, 1557.

¹⁹⁶ *ibid*, 1614.

His initial acquaintances within University College were almost exclusively concerned with instruction in the school and he does not seem to have been introduced to the majority of the professors. However, in March 1861, having been there for precisely one year, he received the following note:

U.C.L.

March 20/61

Dear Sir

I am much obliged to you for your paper on Ripples¹⁹⁷ which I have looked at with interest. The subject is, I suppose, quite new, as to mode of treatment.

If you could find time to call on me in my lecture room, I should be very glad to make your acquaintance. Any day but Saturday at 10 A.M. or 2 P.M. I am pretty sure to be found.

Yours faithfully

A De Morgan¹⁹⁸

Although, as Hirst admitted, "I have not sought his acquaintance although we have been teaching under the same roof for more than a year",¹⁹⁹ the two men finally met a few days after Hirst's receipt of the note. Their initial relationship could best be described as cordial, but not over-friendly, probably because Hirst was very much younger than the elder mathematician. However, there is also evidence that the former seems to have been slightly taken aback by his senior colleague's occasional abruptness and took some time to become accustomed to his rather peremptory manner:

15 June 1862: Yesterday Friday I was at an "at home" at Key's. De Morgan was there, I spoke of my present researches to him; and I must say he treated my communication very coolly. He had no better remark to make than How did you come across that problem? There are such an immense variety of similar questions. It was a kind of pooh pooh in fact. I felt angry with myself at having taken him even so much into my confidence. I ought to have *felt* that interest would not be reciprocal. A dry dogmatic pedant I fear is M. De Morgan notwithstanding his unquestioned ability.²⁰⁰

¹⁹⁷ Thomas Archer Hirst, On ripples and their relation to the velocities of currents, *Philosophical Magazine*, **21** (1861), 188-198.

¹⁹⁸ University College London Archives: London Mathematical Society Papers (hereafter LMS Papers), De Morgan to Thomas Archer Hirst, 20 March 1861.

¹⁹⁹ Brock and MacLeod, *op. cit.*, (193), 1572.

²⁰⁰ *ibid*, 1612.

Fortunately, however, later entries in the diaries reveal that his early impressions were perhaps a little hasty, and that he eventually learnt to overlook the Professor's eccentricities and appreciate the subtleties of De Morgan's sense of humour, to which he would certainly have been exposed between lectures in the professors' common room.

12 November 1865: I never met a man who enjoyed telling a funny story more than de Morgan and he tells them well. It would be worth while to keep a record of some of them. ... [For example], Mr. Stirling Coyne, a barrister, and Albert Smith (of Mont Blanc celebrity) married two sisters who were as like each other as two peas. Coyne was in court one very hot day with a friend. The latter afterwards repaired to the Crystal Palace, there he met a lady whom he took to be Mrs. Coyne. After shaking hands she remarked 'How hot it is here.' 'Yes' replied the gentleman 'but your husband is in a far hotter place I can assure you.' The horror with which this remark was received was inexplicable to the gentleman. It was only afterwards that he discovered he had been addressing the widow of the late mountaineer.²⁰¹

At length, Hirst became a close and trusted colleague, as well as a friend of the De Morgan family.

Due partly to bouts of ill health, plus a desire to devote more time to research, Hirst resigned his post at the school in the summer of 1864.²⁰² However, just over a year later, on 18 August 1865, he "received from Atkinson the Secretary of University College the news of my appointment as Professor of Mathematical Physics. Thus I have reached another step in my career. I have waited long for it and sacrificed much in order to stop in London. I trust I may have health and strength to perform my new duties efficiently."²⁰³ His new work began on 10 October "with a lecture to 25 or 26 students. It passed off well and was listened to with the greatest interest. On Wednesday morning I commenced with my senior class; there were 5 students and a visitor. The latter expressed his satisfaction at the lecture and left a student to hear the course. I have since continued my work every morning and have now altogether about 32 students which represent an income of £162 upon which therefore I shall just be able to live without seeking for extra work."²⁰⁴

²⁰¹ *ibid*, 1759-60.

²⁰² Gardner and Wilson, *op. cit.*, (190), 832.

²⁰³ Brock and MacLeod, *op. cit.*, (193), 1739.

²⁰⁴ *ibid*, 1747.

As far as his teaching was concerned, it would appear that his mode of tuition raised the somewhat desultory standard of instruction which had prevailed in the exposition of mathematical physics under his predecessor. In this he was helped in part by the fact that his newly-created chair allowed him to concentrate on a smaller selection of topics with which he was well-acquainted rather than requiring him to give inadequate tuition in areas which extended beyond his range of expertise.

Junior Class: Prerequisites - Elements of Geometry, Algebra, and Plane Trigonometry.

Content : 1. Elementary Statics, Hydrostatics, and Kinematics.
2. Elementary Dynamics and Optics.
3. The Elements of Plane Astronomy and of the Theories of Sound, Light and Heat.

Senior Class: Prerequisites - Co-ordinate Geometry and Differential and Integral Calculus.

Content : 1. Higher Branches of Statics and Kinematics.
2. Dynamics of particles and of rigid bodies.
3. Hydrostatics and Hydrodynamics.²⁰⁵

But Hirst also attempted to broaden his lecture range by proposing, in 1866, to give a series of evening lectures on the new continental geometrical work with which he was so familiar and which was, after all, his speciality. Permission was obtained from De Morgan for these lectures to go ahead (since the subject was in a branch of pure mathematics), and Hirst spent the summer vacation preparing the course under the title of Modern Geometry. Unfortunately this name was to be the cause of a minor disagreement between the college's two mathematical professors. In a letter of 31 July, De Morgan complained that "I entirely object to the name 'Modern geometry' - because I myself teach what has been known by that name for more than 150 years. ... I affirm, as a matter of fact, that the name is appropriated."²⁰⁶ Instead, he recommended the title of Recent Geometry which, he said, would imply a survey of the work of the last fifty years.

This caused Hirst considerable annoyance, especially since he believed that if, as De Morgan maintained, the name of Modern Geometry had been appropriated, "you must admit that it has also been abandoned. I repeat that *I* have never heard the name applied

²⁰⁵ *University College, London. Calendar. Session 1866-67*, (London: Walton and Maberly, 1866), 20.

²⁰⁶ LMS Papers, De Morgan to Thomas Archer Hirst, 31 July 1866.

to any other subject than the one upon which I propose to lecture."²⁰⁷ Rejecting De Morgan's suggestion, he proposed the following compromise:

The term 'Pure geometry' has frequently been applied as opposed to algebraic or co-ordinate Geometry. It includes however Euclidean Geometry, to which as every body knows you give special attention in your classes. In order to distinguish my subject therefore, without impairing the identity between the latter and the Modern Geometry expounded in recent English textbooks, the term modern would still have to be retained. I see no great objection to the name 'Modern Pure Geometry' and if you think it preferable to the one I first proposed I will adopt it.²⁰⁸

De Morgan, however, was not satisfied. "I utterly deny that the phrase modern geometry - as applied to the wide infinitesimal calculus - has been abandoned," he declared. "So long as standard works are read, their phrases are not abandoned - even if no new use of them be made. ... When you say you *never* heard the phrase, I must take you to mean that you do not recollect ever having heard it."²⁰⁹ He further remarked "that *ancient* and *modern* are in English simple alternatives and *recent* is the word for the fag end of the modern".²¹⁰ Naturally, De Morgan's view prevailed and Hirst's course title was changed to Recent Geometry;²¹¹ however, trivial though it may appear, this dispute very clearly illustrates not only how far mathematics had progressed in the four decades De Morgan had been teaching, but what a vast chasm now existed between his Cambridge-trained understanding of geometry and Hirst's more recent European education.

A combination of their two backgrounds could perhaps be seen in Sylvester who, while certainly a high-ranking Cambridge man, also had a substantial personal knowledge of contemporary European mathematicians and their recent work. However, while firmly siding with Hirst on the matter, he resisted the temptation to correct De Morgan's somewhat outdated opinions, believing that "I should be doing more harm than good by intermeddling with that rather obstinate old gentleman and we all ... agree in feeling that he has yielded so much in substance that he must be allowed to have his own way in the form of announcement which he is certainly not aware leads to create a serious wrong impression as the word Recent applied to Geometry means something quite different

²⁰⁷ *ibid*, Thomas Archer Hirst to De Morgan, 2 Aug. 1866.

²⁰⁸ *ibid*.

²⁰⁹ *ibid*, De Morgan to Thomas Archer Hirst, 4 Aug. 1866.

²¹⁰ *ibid*.

²¹¹ *op. cit.*, (205), 51.

from Modern".²¹² Yet irrespective of its intended meaning, the course's title would have made no difference to the content of Hirst's lectures, the first of which was - or rather, was intended to be - delivered on 16 October 1866. Hirst's diary explains:

Attended at 8.30 P.M. at University College to give my first lecture on '*Recent*' Geometry. No student presented himself. Dr Sharpey²¹³ was the only man who came. The lectures which took me at least a month during my vacation to prepare are thus for the present useless. It is quite clear that the evening class public does not desire to become acquainted with *recent* geometry.²¹⁴

Yet, frustrated as Hirst must no doubt have been at De Morgan's interference, it almost certainly played no part in the lack of response to his course, which was probably of too high a level to have been of interest or use to an evening class audience. Nevertheless, Hirst would surely have felt greatly irritated to have seen his plans undermined, albeit unintentionally, by a fellow professor of mathematics at the college. In reference to this, Sylvester had written to him expressing the hope "that in another year you will have your own way in this matter".²¹⁵ Curiously, by a sequence of events a few months later, this hope was realised, but to a far greater extent than either Sylvester or Hirst could have foreseen. All will be revealed in section 5.3 of the following chapter....

²¹² *ibid*, James Joseph Sylvester to Thomas Archer Hirst, 11 Aug. 1866.

²¹³ William Sharpey (1802-1880), University College's professor of anatomy and physiology from 1836 to 1874.

²¹⁴ Brock and MacLeod, *op. cit.*, (193), 1791.

²¹⁵ LMS Papers, James Joseph Sylvester to Thomas Archer Hirst, 11 Aug. 1866.

Chapter 5

De Morgan and his mathematical students, 1836-1867

5.1 The Student Experience

Thus far, whilst considerable attention has been paid to the mathematical tuition offered at University College during this period, comparatively little has been said about the actual recipients of this instruction. Although one can form a reasonably accurate picture of the work of De Morgan and his fellow professors, details regarding the day to day lives of their students are, perhaps inevitably, harder to determine so precisely. Yet, while references to student activities and experiences are absent from official college publications or documents, there are still plenty of other relevant sources which contain valuable information relating to student life at University College during its early years. The current chapter will therefore exploit this material to focus on the students who attended the college's mathematical lectures at this time and perhaps form some evaluation of De Morgan's influence on them.

Of the sources available, perhaps the most valuable are the memoirs and biographies of alumni who later achieved some degree of celebrity. As shall be seen, De Morgan had more than his fair share of such pupils; consequently, he features, albeit in a minor role, in many of these publications. It is thus from the pages of books such as these that we derive much of our information concerning the experiences of those who studied under him. But not exclusively. Other important sources include material compiled towards the end of the nineteenth century, presumably in preparation for a college history, as well as documents assembled by the historian H. H. Bellot during the 1920s for his monumental account of the college, published in 1929. All contain substantial revelations by former students concerning life at the college in the mid-nineteenth century.

From this abundance of reminiscences, the overwhelming impression one receives is that the college's most memorable characteristic at this time, and certainly the feature which stayed longest in the minds of alumni, was its dull and depressing appearance. Then as now, Gower Street was hardly a particularly vibrant or colourful area of London, and the dreariness of the vicinity appears to have been reflected in the students' perception of their college. An erstwhile medical student, recalling his days

in the college's dissecting rooms during the session of 1839-40, provides an atmospheric indication of the prevailing ambience:

In winter during the term, darkness prevailed by 4 p.m. in this gloomy place. ... Not a sound could be heard even of my own feet upon the soft sawdust. There was only that dull and rolling sound of the traffic in the streets which is peculiar to London, and which came dismally down through the ventilators in the roof.¹

For those to whom city life was new, or even those who travelled in from neighbouring villages such as Hampstead or Highgate, the pollution, the overcrowded streets and the unrelenting drabness of their new environment must have been a dispiriting experience. Yet, despite this apparent air of gloom and monotony, it would seem that the prevailing atmosphere of austerity did not entirely dampen the high spirits of many of the students. Indeed, as *Punch* opined in 1846, with respect to their extra-curricular activities: "We think, as far as vulgarity goes, the concern in Gower Street may vie with the older establishments of the Cam and the Isis."²

Furthermore, notwithstanding the aesthetic shortcomings of their surroundings, students were still able to benefit from the intellectual environment fostered within the college walls:

...in those years London was a place with plenty of intellectual stimulus in it for young men, while in University College itself there was quite enough vivacious and original teaching to make that stimulus available to the full. It is sometimes said that it needs the quiet of a country town remote from the capital, to foster the love of genuine study in young men. But of this, I am sure, that Gower Street, and Oxford Street, and the New Road, and the dreary chain of squares from Euston to Bloomsbury, were the scenes of discussions as eager and as abstract as ever were the sedate cloisters or the flowery river-meadows of Cambridge or Oxford.³

The author of the above recollection was Richard Holt Hutton (1826-1897), a pupil of De Morgan at the college between 1842 and 1845, who went on to distinguish himself in later life as a journalist, eventually serving as joint editor of *The Spectator* for over thirty years.⁴ He is far from the only (or the most famous) student to have

¹ *Notes on the History of University College, London, with a Record of the Session 1886-7. Being the first volume of The University College Gazette*, (London: University College Society, 1888), 37.

² *Punch, or the London Charivari*, 10 (1846), 248.

³ Walter Bagehot, *Literary Studies*, (ed. Richard Holt Hutton), vol. 1, (London: Longmans, Green, and Co., 1879), xiii.

⁴ *D.N.B. 1st Supplement*, 3, 19-22.

achieved eminence following his studies at University College. Indeed, one could point to a host of fellow alumni who would achieve fame in various areas during this period and beyond. Moreover, by virtue of the fact that mathematics was an essential component of the University of London's degree course, nearly all of these distinguished Victorians would have attended the college's mathematical classes at one time or another. The following section will therefore highlight the achievements, mathematical or otherwise, of some of those who experienced the teaching of Augustus De Morgan.

5.1.1 De Morgan's principal students

Jacob Waley (1818-1873) has already received brief notice in the two preceding chapters, both as a friend and private pupil of De Morgan, as well as the first person to graduate with honours in mathematics from the University of London. Sophia De Morgan writes that he "was one of the first Jewish students, after my husband's return to his Professorship, of whom the College had reason to be proud",⁵ not only for his great distinction in the B.A. examinations for both mathematics and classics, but also because he was the first to be awarded the degree of M.A. by the University in 1840. A further mark of the excellence of his academic achievements is evinced by his election to one of the first college Fellowships, shortly after the creation of this distinction in 1842.⁶

But Waley's academic brilliance was not limited to mathematics and the classics. Following his university career, he qualified as a lawyer, earning a reputation as one of the most learned conveyancers in the profession. He was also a highly active and respected member of the Jewish community, being jointly responsible for the creation of the United Synagogue as well as the first president of the Anglo-Jewish Association.⁷ Yet in addition to his many other commitments, he still retained strong links with his former college. Most particularly, noticing that they had been unable to offer instruction in political economy since the resignation of John McCulloch in 1837, he persuaded the council to let him deliver a course of lectures on the subject in early 1854.⁸ So impressed were they with his tuition, that they offered him the

⁵ Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, and Co., 1882), 102.

⁶ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1844*, (London: Richard and John E. Taylor, 1844), 7.

⁷ *D.N.B.*, **59**, 34-35.

⁸ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1853*, (London: Taylor and Francis, 1853), 6.

professorship,⁹ which he accepted,¹⁰ continuing to teach in tandem with his other duties until 1866.

One of the first distinctions Waley achieved during his academic career had marked another significant event in the college's history - the award of its first scholarship. This had been made possible by a very generous endowment from a peculiar source, as council member Henry Crabb Robinson recorded in his diary for 1 November 1836:

An old lady, upwards of eighty, has announced her intention of giving £5,000 to the University.¹¹ She declares her object to be the support of civil and religious liberty. She herself is a Catholic. Her name is [Mary] Flaherty. Lord Brougham said, that having ascertained that she was in the full possession of her faculties, and that she had no near relations having a moral claim on her, he felt no scruple in accepting the gift. He had learned also that she spent very little on herself, and devoted a handsome income mainly to acts of beneficence.¹²

In thanking Mrs Flaherty for her extraordinary munificence, the council assured her "that her gift will be carefully applied in the manner which they deem the most effectual for the furthering of the great objects of the Institution".¹³ The system decided upon was announced in July 1837. This was the creation of the college's Flaherty Scholarships to the value of £50 per annum, tenable for up to four years, "to be given alternately, one year to the best proficient in Mathematics and Natural Philosophy, the next year to the best proficient in Classics".¹⁴ All college students of one year's standing were entitled to compete, provided they were under the age of twenty.

The first competition (for the mathematical scholarship) was held in October 1838. By the criteria drawn up for the contest, there were three examiners: the college's professors of mathematics and natural philosophy, plus one other, to be appointed by the council. On this occasion, the examiners were De Morgan, Sylvester and

⁹ UCL College Correspondence ('UCC'), No. AM/70, Report of the Committee appointed to consider Mr Waley's application, [June 1854].

¹⁰ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February 1855*, (London: Taylor and Francis, 1855), 8.

¹¹ i.e. University College.

¹² Thomas Sadler (ed.), *Diary, Reminiscences, and Correspondence of Henry Crabb Robinson*, (London: Macmillan and Co., 1869), vol. 3, 100-101.

¹³ UCC, No. 4488, Report by C. C. Atkinson on the Flaherty bequest, [1836].

¹⁴ *University College, London. Proceedings at the Annual General Meeting of Proprietors, 27th February, 1839*, (London: Richard and John E. Taylor, 1839), 40.

Olinthus Gregory.¹⁵ In addition to Waley, there was only one other candidate, Thomas Cubitt. Faced with such a gifted opponent, it was to Cubitt's credit that "the Examiners in their announcement of the award of the Scholarship to Mr. Waley, specially stated to the Council, that the attainments of the unsuccessful Candidate were such, that they should not have hesitated one moment on the question, whether or no a Scholarship should have been awarded to him, if he had been the only Candidate".¹⁶ Waley's was the first of six mathematical Flaherty Scholarships awarded before the system was changed in 1850.

The creation of the Flaherty Scholarship was not the only product of a generous benefaction during this time. In chapter 3, we drew attention to the fact that in 1833 the council, via Lord Brougham, had also received a donation of £1000 from an anonymous benefactor under the name of "A Patriot". This donation had been further supplemented from the same source at various points during the 1830s until, by 1839, the total sum amounted to £2800. After much discussion, Brougham finally proposed "that the Interest of the Patriot Fund should be applied in procuring, at a reduced rate of payment, admission to certain Classes of the College for such Schoolmasters of the Metropolis and the Neighbourhood as are desirous of availing themselves of the advantage".¹⁷

The result was the inauguration of evening classes in Latin, Greek, mathematics and natural philosophy to masters of unendowed schools. From this time onwards, De Morgan delivered a course of fifteen weekly lectures on Fridays between 7 and 9 p.m. from October to mid-February, with Sylvester (and succeeding professors of natural philosophy) lecturing on Wednesday evenings between February and June.¹⁸ The reduced admission fee was £1 10s for all four subjects, or £1 for one. At their commencement in 1839, there were 33 students registered for all of the classes, with a further three opting for mathematics alone.¹⁹ Although the majority of attendants were merely aiming to increase their knowledge in order to improve their teaching,²⁰ a few had more ambitious objectives. One in particular proved to be a quite exceptionally gifted scholar.

¹⁵ *The Times*, 30 October 1838, 4e.

¹⁶ *op. cit.*, (14), 7.

¹⁷ *ibid.*

¹⁸ *University College, London. Session 1839-40. Faculty of Arts and Laws*, (London: Richard and John E. Taylor, 1839), 12.

¹⁹ *op. cit.*, (14), 8.

²⁰ Interestingly, one of those who chose to attend De Morgan's classes during the 1861-62 session was perhaps his most qualified student, being probably the only mathematics teacher in London at this time to have a PhD: Thomas Archer Hirst.

Isaac Todhunter (1820-1884) was born in Rye, Sussex, on 23 November 1820. Described as an "unusually backward"²¹ child, he was sent to a school in Hastings and subsequently to one newly opened by a Mr. J. B. Austin from London. Around 1835, Todhunter moved with Austin to a school in Peckham where he became assistant master. It was while he was thus employed that, between 1839 until 1842, he managed to attend the evening lectures of Key, Malden, Sylvester and De Morgan at University College. He always held himself greatly indebted to all of them, but especially to the last, for whom his admiration was "unbounded".²² It was from this "venerated master and friend"²³ he derived "that interest in the history and bibliography of science, in moral philosophy and logic, which determined the course of his riper studies".²⁴

Since those who attended the college's evening classes were regarded as students of the college, they were equally entitled to obtain professors' certificates and thus to submit themselves to examination for degrees of the University of London. Having studied at the college for three years, Todhunter took advantage of this privilege and in 1842 graduated B.A. and obtained the University's mathematical scholarship.²⁵ Two years later, on proceeding to the M.A. degree, he obtained the gold medal awarded for that examination as well as prizes for Greek and Hebrew. Concurrently with these studies, from 1841 he filled the post of mathematics master in a large school at Wimbledon.

On 4 May 1844, acting on De Morgan's advice, he entered St. John's College, Cambridge, graduating in 1848 with the senior wranglership and the first Smith's prize.²⁶ The following year, he was elected a fellow of St. John's. From this time he was mainly occupied as college lecturer and private tutor, and in the compilation of the numerous mathematical treatises, chiefly educational, by which he became widely known. Of these, his *Euclid* (1st ed. 1862) attained an enormous circulation, reaching seven editions; while his *algebra* (1858), *trigonometry, plane and spherical* (1859), *mechanics* (1867), and *mensuration* (1869), all became standard textbooks, remaining so until the beginning of the twentieth century. They secured a vast

²¹ John E. B. Mayor, *In Memoriam: Isaac Todhunter*, (Cambridge: Macmillan and Bowes, 1884), 43.

²² *ibid.*, 44.

²³ Alexander MacFarlane, *Lectures on Ten British Mathematicians of the Nineteenth Century*, (London: Chapman and Hall, 1916), 142.

²⁴ Mayor, *op. cit.*, (21), 3.

²⁵ *University College, London. Proceedings at the Annual General Meeting of Members of the College, 22nd February, 1843*, (London: Richard and John E. Taylor, 1843), 7.

²⁶ John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 6, 199.

readership, and, being adopted by the Indian government, were translated into Urdu and other oriental languages.

Besides being a sound Latin and Greek scholar, he was also familiar with French, German, Spanish, Italian, Russian, Hebrew, Arabic, Persian and Sanskrit. He was well versed in the history of philosophy, and was one of the chief founders of the moral science examination at Cambridge, acting as examiner from 1863-65. He was also responsible for editing posthumous works by two other prominent scientific figures. In 1865, he published the second edition of George Boole's *Treatise on Differential Equations* and, eleven years later, the literary and scientific correspondence of William Whewell. Todhunter is primarily remembered today for his many valuable contributions to the history of mathematical study. These were lengthy histories of the calculus of variations (1861), probability (1865), the theories of attraction and the figure of the earth (2 vols, 1873) and elasticity (2 vols, 1886-93), a posthumous publication edited by Karl Pearson.²⁷ These remain valuable reference books to this day, although Todhunter's literary style hardly makes them light reading.

The year of Todhunter's departure from University College (1842) saw the arrival of two more distinguished mathematical scholars into De Morgan's regular classes: Richard Holt Hutton and Walter Bagehot (1826-1877). Hutton, the son of a Unitarian minister, was born in Leeds, but his family had moved to London in 1835, where he attended University College School before entering the main classes. Bagehot hailed originally from Somerset, receiving his schooling in Bristol before moving to London to begin his college career. The two young men quickly became friends, sharing many common interests, including a fascination for (and ability in) De Morgan's mathematical classes, where they were particularly intrigued by the various philosophical issues arising from his lectures.

As Hutton later recalled, "in Mr. De Morgan's time, the Mathematical classes of University College were quite as much classes in Logic, at least in the Logic of number and magnitude, as in Mathematics".²⁸ It is not surprising, therefore, that "one of the chief subjects of discussion between us used to be the logical questions raised in the Mathematical classes, especially in [De Morgan's] lectures on the theory of limits, the theory of probabilities, the calculus of operations, and the interpretation of symbols applied".²⁹ Indeed, on one occasion, "in the vehemence of our argument as

²⁷ He will be discussed in chapter 6.

²⁸ S. E. De Morgan, *op. cit.*, (5), 97.

²⁹ *ibid.*

to whether the so-called logical principle of identity (A is A) were entitled to rank as 'a law of thought' or only as a postulate of language, Bagehot and I wandered up and down Regent Street for something like two hours in the vain attempt to find Oxford Street".³⁰

Both students performed skilfully in college and university examinations, Hutton obtaining the university mathematical scholarship on taking his B.A. degree in 1845; Bagehot duplicating this achievement a year later.³¹ Both also won the university's gold medal for logic, moral philosophy, political philosophy and political economy in their M.A. examinations: Bagehot in 1848, Hutton in 1849.³² In 1855, they assumed the joint editorship of *The National Review*, following which both men went on to become distinguished literary figures, Hutton at the helm of *The Spectator*, and Bagehot as editor of *The Economist*, in which position he wrote *The English Constitution* (1867) which remains the work by which his name is best remembered.³³

In a speech delivered at the distribution of prizes to pupils of University College School in August 1848, De Morgan drew special attention to the growing number of students who, prior to gaining distinctions in his classes, had received instruction at the school.³⁴ Of these he highlighted the achievements of two of his current students, Edward John Routh (1831-1907) and Francis Guthrie (1831-1899). Routh had entered the main college in 1846, winning a university exhibition in mathematics when he matriculated the following year. He went on to obtain both the Flaherty Scholarship, the university's mathematical scholarship for his degree examination in 1849, and four years later was awarded the gold medal for mathematics and natural philosophy when he took his M.A. degree. In the meantime, he moved to Cambridge, where he beat James Clerk Maxwell into second place in the Tripos of 1854.³⁵ During the next thirty years he was to become one of the most successful private

³⁰ Bagehot, *op. cit.*, (3), xiii-iv.

³¹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 25th February, 1846*, (London: Richard and John E. Taylor, 1846), 6; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 24th February, 1847*, (London: Richard and John E. Taylor, 1847), 5.

³² *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1849*, (London: Richard and John E. Taylor, 1849), 5; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 27th February, 1850*, (London: Richard and John E. Taylor, 1850), 5.

³³ *D.N.B.*, 2, 393-396.

³⁴ *Junior School of University College, London. Distribution of Prizes, August 4, 1848. Speech of Professor De Morgan, delivered at University College, London, Friday, August 4th, 1848, on occasion of the Annual Distribution of Prizes to the Pupils in the Junior School*, (London: Richard and John E. Taylor, 1848), 1-2.

³⁵ *D.N.B. Supplement 1901-1911*, 233-235, p.233.

coaches in the history of the Tripos, training an unprecedented 48% of the wranglers who graduated between 1862 and 1888, including 28 Senior Wranglers and 43 Smith's prizemen.³⁶

Interestingly, the Senior Wrangler in the year after Routh had also studied at University College under De Morgan. James Savage (1833-1855) had entered his mathematical class in 1847, aged only fourteen. Matriculating in 1850, his career followed a similar pattern to that of Routh: the university exhibition in mathematics for his matriculation examination was followed by the university scholarship in mathematics and natural philosophy when he took his degree two years later, and a gold medal for his M.A. in 1854. He too went to Cambridge, emerging as Senior Wrangler and first Smith's prizeman in January 1855. Tragically, however, this is where the similarity between the two men's careers ends. A few months after his Tripos success, Savage was reportedly "missed from his rooms in College, found dead by a labourer in a dry ditch at Comberton, Apr. 20, 1855; the coroner's inquest, held at Madingley, returned a verdict 'died in a fit of apoplexy'".³⁷

A less calamitous story is that of Routh's school classmate Francis Guthrie. After acquiring University of London degrees in both mathematics and law,³⁸ he practised as a barrister before moving to South Africa, where he became professor of mathematics in the newly-established Graaff-Reinet College, Cape Colony, in 1861. Fifteen years later, he obtained the chair of mathematics at the South African College in Cape Town, where he remained for the rest of his life. He published a few mathematical papers, but also had other academic interests, particularly botany where, for his work on the genus *Erica*, he is commemorated by *Erica Guthriei*.³⁹ His chief claim to mathematical fame is derived from a now legendary conversation to which he himself was not a party. This occurred some two years after he had left University College, between his former teacher and his younger brother.

Frederick Guthrie (1833-1886) had entered De Morgan's mathematical classes three years after his brother, in 1849. It was in October 1852, during his final year at the college, that he approached the professor with a mathematical problem. So struck

³⁶ Venn, *op. cit.*, (26), 5, 367.

³⁷ *ibid*, 426.

³⁸ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 26th February, 1851*, (London: Richard Taylor, 1851), 5; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1853*, (London: Taylor and Francis, 1853), 5.

³⁹ Norman L. Biggs, E. Keith Lloyd and Robin J. Wilson, *Graph Theory 1736-1936*, (Oxford: Clarendon Press, 1976), 216.

was De Morgan by this question that he immediately related the story in a letter to his friend William Rowan Hamilton in Ireland:

A student of mine asked me today to give him a reason for a fact which I did not know was a fact - and do not yet. He says that if a figure be anyhow divided and the compartments differently coloured so that figures with any portion of common boundary *line* are differently coloured - four colours may be wanted, but not more... My pupil says he guessed it in colouring a map of England. The more I think of it, the more evident it seems.⁴⁰

Further information regarding the origin of this problem is provided in an article, written by the younger Guthrie in 1880. It was here that his brother was first credited with its formulation:

Some thirty years ago, when I was attending Professor De Morgan's class, my brother, Francis Guthrie, who had recently ceased to attend them (and who is now professor of Mathematics at the South African University, Cape Town), showed me the fact that the greatest necessary number of colours to be used in colouring a map so as to avoid identity of colour in lineally contiguous districts is four. ... With my brother's permission I submitted the theorem to Professor De Morgan, who expressed himself very pleased with it; accepted it as new; and as I am informed by those who subsequently attended his classes, was in the habit of acknowledging whence he had got his information. If I remember rightly, the proof which my brother gave did not seem altogether satisfactory to himself; but I must refer to him those interested in the subject. I have at various intervals urged my brother to complete the theorem in three dimensions, but with little success...⁴¹

This was the origin of the famous Four-Colour Conjecture, one of the most important problems in the development of modern graph theory, which remained "both the simplest and most fascinating unsolved problem of mathematics"⁴² for many years. While De Morgan believed that four colours were sufficient, he was unable to prove this, or to find a case where five colours were required. The problem was revived in the 1870s when Arthur Cayley and the American Charles Sanders Peirce (1839-1914) both tried in vain to prove it. Independent proofs published by

⁴⁰ Letter from De Morgan to William Rowan Hamilton, 23 October 1852, quoted in Biggs, Lloyd and Wilson, *ibid*, 90-91.

⁴¹ Frederick Guthrie, Note on the colouring of maps, *Proceedings of the Royal Society of Edinburgh*, **10** (1880), 727-728.

⁴² Kenneth O. May, The origin of the four-color conjecture, *Isis*, **56** (1965), 346-348.

Alfred Kempe (1849-1922)⁴³ and Peter Tait (1831-1901)⁴⁴ were both later shown to be defective.⁴⁵ Further work on the problem continued during the twentieth century, culminating in Kenneth Appel and Wolfgang Haken's computer-based proof, presented to the American Mathematical Society on 26 July 1976.⁴⁶ This involved an electronic analysis of over 100,000 different cases, comprising six months of computer time - a method all but inconceivable to the mathematicians who had first attempted to prove the theorem. It had taken the evolution of computing methods beyond the power of any human to solve a problem which had seemed so obvious to De Morgan and his 19 year-old student 124 years before.

Another successful former student whose career began at University College School was William Stanley Jevons (1835-1882), who, after attending college lectures between 1851 and 1853, spent some time in Australia before returning to London to resume his studies towards the end of 1859. Both periods of study saw him achieve college distinctions; for example, the annual report for 1853 records his attainment of commendations in De Morgan's higher junior mathematical class, a silver medal in chemistry, as well as a university prize in botany.⁴⁷ In 1860, he was awarded the college's Ricardo Scholarship in political economy⁴⁸ winning the university's gold medal for his M.A. in logic, moral philosophy, political philosophy and political economy in 1862.⁴⁹ Best remembered today for his work in economics, Jevons was appointed professor of political economy at Owen's College in Manchester (now Manchester University) in 1866, returning to London to fill the same chair at University College in 1875.⁵⁰

In 1852, he had begun to keep a diary. This shows him to have been greatly impressed by mathematics as taught by De Morgan, although he claimed "I was

⁴³ Alfred Bray Kempe, On the geographical problem of the four colours, *American Journal of Mathematics*, **2** (1879), 193-200.

⁴⁴ Peter Guthrie Tait, Note on a theorem in the geometry of position, *Transactions of the Royal Society of Edinburgh*, **29** (1880), 657-660.

⁴⁵ Percy John Heawood, Map-colour theorem, *Quarterly Journal of Pure and Applied Mathematics*, **24** (1890), 332-338.

⁴⁶ Kenneth Appel and Wolfgang Haken, Every planar map is four colorable, *Bulletin of the American Mathematical Society*, **82** (1976), 711-712.

⁴⁷ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1853*, (London: Taylor and Francis, 1853), 5, 6.

⁴⁸ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 27th February, 1861*, (London: Taylor and Francis, 1861), 6.

⁴⁹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 25th February, 1863*, (London: Taylor and Francis, 1863), 8.

⁵⁰ *D.N.B.*, **29**, 374-378.

never bright or successful in his class, in spite of working hard".⁵¹ This is certainly modesty on Jevons' part as his later research in both economics and logic reveals not only mathematical ability and erudition, but also suggests the wide-ranging influence of De Morgan's lectures, for example in his pioneering application of quantitative techniques to economics. In the words of Richard Hutton to Sophia De Morgan, "no one has made better use of the time passed in those delightful classes; and every book he publishes bears witness to the help he has derived from your husband's teaching".⁵² It is perhaps ironic, therefore, that his important research on symbolic logic, published during the 1870s, shows far greater adherence to the innovative work of George Boole than that of his former teacher, with which he would certainly have been thoroughly acquainted.

Robert Bellamy Clifton (1836-1921) was another distinguished student in whose progress De Morgan took particular pride since, in the words of his widow, "My husband early perceived talents in Mr. Clifton which had been ignored by former teachers, and the result justified his advice and predictions".⁵³ Clifton entered De Morgan's classes in 1851, staying at the college for four years. However, he does not appear to have entered for any university examinations during that time, possibly not even matriculating. Nevertheless, presumably on the advice of his professor, in 1855 he entered St. John's College, Cambridge, from where he emerged four years later as sixth wrangler and second Smith's prizeman. He soon established himself as a prominent experimental physicist, being appointed professor of natural philosophy at Owen's College in 1860. Five years later, he became professor of experimental philosophy at Oxford, a post he was to hold for fifty years, during which time he would design and establish the University's Clarendon Laboratory.⁵⁴

A prominent characteristic among many of De Morgan's ex-students after their graduation was a significant vocational tendency towards the legal profession. In fact, some acquired substantial eminence in the practice. One such pupil achieved this while also attaining a reputation as a first class mathematician. This was Charles James Hargreave (1820-1866) who was an outstanding student at the college for seven years between 1836 and 1843, attending De Morgan's lectures for the first four, during which time he won the second mathematical Flaherty Scholarship in 1840.⁵⁵ So highly was he regarded by his professors that, almost immediately on

⁵¹ Harriet Ann Jevons (ed.), *Letters and Journal of W. Stanley Jevons*, (London: Macmillan & Co., 1886), 88-89.

⁵² S. E. De Morgan, *op. cit.*, (5), 97.

⁵³ *ibid.*, 98.

⁵⁴ Venn, *op. cit.*, (26), 2, 68.

⁵⁵ UCC, Charles James Hargreave to Charles C. Atkinson, 18 Dec. 1843.

receiving his law degree from the University of London (as well as the scholarship in law), he was appointed professor of jurisprudence at the college⁵⁶ in consequence of the resignation of the previous incumbent John Thomas Graves (1806-1870), another very capable mathematician.

Hargreave held the chair for six years until 1849 when, following the passage of the Famine and Incumbered Estates Act, he became one of the three commissioners appointed to administer the sale of incumbered estates in Ireland. Nine years later, he was appointed a judge of the newly-created Landed Estate Court, a post he held until his death. Yet, despite these professional commitments, throughout this time he was able to publish numerous mathematical papers, including several of some significance. One of these, 'On the solution of linear differential equations' (*Philosophical Transactions of the Royal Society*, (1848), 31-54) won him the gold medal of the Royal Society, to which he had been elected a Fellow in 1844.⁵⁷

Considering University College's unique secularity at this time, it is only to be expected that many of De Morgan's students would be of the Jewish faith. It is therefore hardly surprising that James Joseph Sylvester, though among the earliest, was certainly not the only such student who would acquire a distinguished academic reputation both within the college and beyond. Similarly, Jacob Waley was far from unique in being an outstanding scholar of Jewish extraction who later achieved eminence as a lawyer. Possibly the most famous of such students was George (later Sir George) Jessel (1824-1883) who, following the 'usual' honours (Flaherty Scholarship, 1844; university mathematical scholarship, 1843; university gold medal in mathematics and natural philosophy, 1844), practised law for twenty-five years before being appointed Master of the Rolls in 1873.⁵⁸

Another Jewish student who later became an important legal figure was Arthur Cohen (1829-1914). Following three years of study in Gower Street, he entered Magdalene College, Cambridge, in 1849, coming out as fifth wrangler in 1853. Entering the Inner Temple, he was called to the Bar in 1857, becoming a Q.C. in 1874, serving as council to the Secretary of State and chairman of the Bar Council, as well as being president of the Jewish Board of Deputies. Yet, eminent as his subsequent career may have been, academically he appears slightly less remarkable than other alumni so far mentioned, not having won any scholarships or prizes either

⁵⁶ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1844*, (London: Richard and John E. Taylor, 1844), 6.

⁵⁷ *D.N.B.*, **24**, 379-380.

⁵⁸ *ibid*, **29**, 368-370.

in London or Cambridge. What *is* particularly noteworthy about him is that in 1858, five years after his Tripos result, for no known reason, he was awarded a B.A. degree, thus making him the first professing Jew to graduate at Cambridge.⁵⁹

Possibly the last of De Morgan's students to achieve mathematical distinction was another of his outstanding Jewish pupils, Numa Edward Hartog (1846-1871). A measure of Hartog's academic brilliance is illustrated by the list of his achievements in his final college examinations of 1864: "the Prize in the Higher Senior Class of Latin, the Prize in the Higher Senior Class of Greek, the Special Certificate in the Higher Senior Class of Mathematics, the Special Certificate in the Senior Mathematical Class of Natural Philosophy and Astronomy, the first Prize in the Class of Philosophy of Mind and Logic, and the Prize in the Class of History of Moral Philosophy."⁶⁰ On gaining his degree at the University of London in 1864, he won scholarships in both mathematics and classics,⁶¹ entering Trinity College, Cambridge, the following year. His performance as the Senior Wrangler and second Smith's prizeman of 1869, prompted the award of a Cambridge degree by special Grace of the Senate, exempting him from taking the usual oath.⁶² Not long after this, it was largely thanks to his efforts that a Parliamentary bill was passed, on 16 June 1871, finally abolishing religious tests in the Universities of Oxford and Cambridge. He died of smallpox three days later.⁶³

From this brief selection of De Morgan's students, some information may be gleaned regarding the varied careers followed by the most distinguished of the University of London's early graduates, in fields such as law, economics and the media, as well as mathematics. In view of their eminence, many of these high-achievers went on to publish memoirs in later life, with several students whose names are less well known also leaving similar recollections. Not all include detailed reminiscences of their college days, but, of those that do, several contain anecdotes relating to their time in De Morgan's lectures. It is with the aid of such accounts that we are able to give an indication not only of the level of appreciation of his teaching, but also of the average student's mathematical workload during this time. The next section will go some way to providing this information; but first it would be instructive to employ these sources to see how the Professor was viewed by his pupils.

⁵⁹ Venn, *op. cit.*, (26), 2, 85.

⁶⁰ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1865*, (London: Taylor and Francis, 1865), 7.

⁶¹ *ibid*, 8.

⁶² Venn, *op. cit.*, (26), 3, 273.

⁶³ *D.N.B.*, 25, 73-74.

5.1.2 Student accounts

Towering up intellectually above all his fellows, as I now look back upon him, rises the grand form of the mathematician, Augustus De Morgan, known, I suppose to each succeeding generation of his pupils as 'Gussy'. A stout and tall figure, a stiff rather waddling walk, a high white cravat and stick-up collars in which the square chin is buried, a full but well chiselled face, very short-sighted eyes peering forth through gold-rimmed spectacles; but above all such a superb dome-like forehead, as could only belong to one of the kings of thought: that is my remembrance of De Morgan, and I feel in looking back upon his personality that his is one of the grandest figures that I have known.⁶⁴

Thus wrote the historian Thomas Hodgkin (1831-1913) more than half a century after experiencing the teaching of De Morgan in the late 1840s. Although he would have attended the mathematical classes as a necessary prerequisite for a University of London degree, Hodgkin's own academic forte was classics, in which he graduated with honours in 1851.⁶⁵ Yet, despite the fact that mathematics was probably not his favourite or principal subject of study while at University College, the Professor clearly left a profound impression on him. Furthermore, Hodgkin was not the only non-mathematician on whom De Morgan's teaching made a substantial impact. Reminiscing in 1921, the lawyer James Bourne Benson (1848-1930) affirmed that "De Morgan [was] looked upon with awe"⁶⁶ by the undergraduates of his day. The distinguished chemist, Sir Henry Enfield Roscoe went further still, opining that De Morgan was more than "merely a mathematician and a unique teacher; he was one of the profoundest and subtlest thinkers of the nineteenth century".⁶⁷

Admiration for De Morgan's high intellect was thus clearly a factor in securing respect from his students, regardless of their mathematical ability. However, this alone does not account for the numerous laudatory accounts of his work as professor; after all, academic prowess does not imply ability to teach. Yet, according to Roscoe, "De Morgan was certainly *facile princeps* among the teachers of mathematics of his day, and he inspired the greatest enthusiasm for the subject in the

⁶⁴ Thomas Hodgkin, University College, London, Fifty Years Ago, *The Northerner*, (1901), 1, 75; quoted in Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 80.

⁶⁵ *D.N.B. 1912-1921*, 259-260.

⁶⁶ James Bourne Benson, "Some Recollections of University College in the Sixties", MS (1921), University College Archives, Materials for the history of UCL, Mem. 1B/3, f.3.

⁶⁷ Henry Enfield Roscoe, *The Life and Experiences of Sir Henry Enfield Roscoe*, (London: Macmillan & Co., 1906), 25.

minds of his pupils".⁶⁸ It would seem from this, and other accounts by former students, that De Morgan's innate mathematical propensity was enriched by strong communicative skills which, together with a talent for presenting complex ideas in an intelligible form and a pithy lecturing style, resulted in the ability to captivate his audience irrespective of the topic he was treating. As Stanley Jevons recounted:

As a teacher of mathematics De Morgan was unrivalled. He gave instruction in the form of continuous lectures delivered extempore from brief notes. The most prolonged mathematical reasoning, and the most intricate formulae, were given with almost infallible accuracy from the resources of his extraordinary memory. De Morgan's writings, however excellent, give little idea of the perspicuity and elegance of his *viva voce* expositions, which never failed to fix the attention of all who were worthy of hearing him.⁶⁹

In his obituary of the Professor for the Royal Astronomical Society, Arthur Cowper Ranyard - of whom more presently - elaborated on this faculty for verbal exposition:

He had a method of interesting his hearers in the subjects on which he lectured, and of making them love mathematics for its own sake, to which few other men have ever attained. He devoted more time and labour to the logical processes by which the various rules are demonstrated than to the more technical parts of his subject, though of these too, in their proper place, Professor De Morgan was never unmindful, spending the greatest care on teaching the art of rapid and accurate computation. His exposition of the elementary principles of the Differential Calculus, and of the logical processes of his Double Algebra, was most masterly and exhaustive, and was often enlivened by such humorous illustration that it never failed to impress itself upon the minds of his hearers.⁷⁰

Another student, Sedley Taylor (1834-1920), who attended De Morgan's lectures in the early 1850s, provided further details of what it was about them that students found so enthralling:

De Morgan's exposition combined excellences of the most varied kinds. It was clear, vivid, and succinct - rich too with abundance of illustration always at the command of enormously wide reading and an astonishingly retentive memory. A voice of sonorous sweetness, a grand forehead, and a profile of classic beauty, intensified the impression of commanding power which an almost equally complete

⁶⁸ *ibid.*

⁶⁹ William Stanley Jevons, De Morgan, *Encyclopædia Britannica*, 11th edition, (Cambridge: Cambridge University Press, 1910), 8, 8-10, p.8.

⁷⁰ Arthur Cowper Ranyard, Obituary notice of Augustus De Morgan, *Monthly Notices of the Royal Astronomical Society*, 32, (1871-72), 112-118, p.115.

mastery over Mathematical truth, and over the forms of language in which he so attractively arrayed it, could not fail to make upon his auditors. ... The fundamental conceptions of each main department of Mathematics were dwelt upon and illustrated in such detail as to show that, in the judgment of the lecturer, a thorough comprehension and mental assimilation of great principles far outweighed in importance any mere analytical dexterity in the application of half-understood principles to particular cases. Thus, for instance, in Trigonometry, the wide generality of that subject, as the science of undulating or periodic magnitude, was brought out and insisted on from the very first. In like manner the Differential Calculus was approached through a rich conglomerate of elementary illustration, by which the notion of a differential coefficient was made thoroughly intelligible before any formal definition of its meaning had been given.⁷¹

To students who attended his lectures, the two qualities which were most apparent in De Morgan's teaching were "the love of scientific truth for its own sake, and the utter contempt for all counterfeit knowledge, with which he was visibly possessed, and which he had an extraordinary power of arousing and sustaining in his pupils."⁷² It would appear from more than one source that, as with other areas of his instruction, in order to foster these correct notions in his students, De Morgan's keen sense of humour was often employed as a pedagogic tool, as Richard Hutton explains:

One thing which made his classes lively to men who were up to his mark, was the humorous horror he used to express at our blunders, especially when we took the conventional or book view instead of the logical view. The bland "hush!" with which he would suppress a suggestion which was simply stupid, and the almost grotesque surprise he would feign when a man betrayed that, instead of the classification by logical principles, he was thinking of the old unmeaning classification by rule in the common school-books, were exceedingly humorous, and gave a life to the classes beyond the mere scope of their intellectual interests. I think all my fellow-pupils would agree that never was there a more curious mixture of interests than the prepared discussions of principle in his lectures, and the Johnsonian force and sometimes fun of *his* part in the short dialogues with his pupils which occurred from time to time.⁷³

These occasional verbal interactions were far from being De Morgan's only informal contact with his pupils. Indeed, according to Roscoe, "the trouble he took with his students was extraordinary".⁷⁴ Other recollections also reveal how conscientiously

⁷¹ S. E. De Morgan, *op. cit.*, (5), 99, 100.

⁷² *ibid*, 99-100.

⁷³ *ibid*, 97-98.

⁷⁴ Roscoe, *op. cit.*, (67), 25.

the Professor discharged his duties in monitoring their progress throughout their course of study:

De Morgan was far from thinking the duties of his chair adequately performed by lecturing only. At the close of every lecture in each course he gave out a number of problems and examples illustrative of the subject which was then engaging the attention of the class. His students were expected to bring these to him worked out. He then looked them over, and returned them revised before the next lecture. Each example, if rightly done, was carefully marked with a tick, or if a mere inaccuracy occurred in the working it was crossed out, and the proper correction inserted. If, however, a mistake of *principle* was committed, the words 'show me' appeared on the exercise. The student so summoned was expected to present himself on the platform at the close of the lecture, when De Morgan would carefully go over the point with him privately, and endeavour to clear up whatever difficulty he experienced. The amount of labour thus involved was very considerable, as the number of students in attendance frequently exceeded one hundred.⁷⁵

The high regard in which he was held by his students was, according to his wife, "not gained by any laxity of discipline, for he was strict, especially as to quietness and punctuality".⁷⁶ However, it would be inaccurate to portray De Morgan as the ideal teacher, universally venerated by colleagues and students alike, who never had to face a disorderly class throughout his entire career. While it is certainly true that he was highly esteemed in the college and never exposed to the level of mockery inflicted on professors such as Potter, like any teacher De Morgan had to face his fair share of ridicule from the more immature members of his class.

The professor was blind of one eye and very stout, and had many peculiarities of voice and manner which often created diversion among the youths who attended his class, and many were the tricks played upon him; for, although generally respected, his peculiarities made him something of a butt to those who were too stupid to understand the value of his admirable instruction. On one occasion a number of sparrows were let loose in the lecture-room and flew about, perching on the blackboard, much to the amusement of the audience, who expected every moment that one would alight on the professor's bald head. After some time his attention was drawn to their presence, and he remarked, resting his nose on his pointer, as was his wont, and surveying the class with his only eye, from behind a very large white choker: "I see nothing to laugh at if a sparrow does come into the room, and I daresay there are many here who have not

⁷⁵ S. E. De Morgan, *op. cit.*, (5), 99.

⁷⁶ *ibid*, 101.

got the brains of a sparrow." After which the lecture proceeded without interruption.⁷⁷

Of De Morgan's refusal to compromise on matters of discipline, no better example exists than his occasional clashes with students over punctuality, on which he placed great emphasis. Indeed, he was apparently "so punctual and so regular in the performance of his college duties that his passage to and from his classes served as a time-piece to observant students".⁷⁸ Not surprisingly, he was far from tolerant of those who were unable to imitate this regularity. Shortly after his return to the college in 1836, he became increasingly annoyed by the habit of some of the students of coming into his lecture room a few minutes after the bell had rung to announce the commencement of the morning lecture. At the beginning of March 1838, after warning his students against late arrival, he ordered that the doors of his room be locked after the first five minutes. This prompted a series of complaints from students who found themselves refused admission to his lectures on the grounds of lateness, including the following petition:

To the Senate of University College, London

We, the undersigned Students of the Mathematical Classes of University College, beg respectfully to lay before the Senate of this College, our reasons for protesting against the recent regulation which Professor De Morgan has attempted to establish in his various classes; viz "that the doors of his class room shall be locked five minutes after the ringing of the bell."

In protesting against this regulation we beg at the same time distinctly to state that we find not the least fault with the attention which Professor De Morgan pays to his class but still we feel it our duty respectfully but firmly to remonstrate against a regulation which in our opinion is in the highest degree unjust and inexpedient. We beg to remind the Senate that this regulation is not one which is acted on by the other Professors and was only recently attempted to be enforced by Professor De Morgan. That though we admit the right of any Professor to make whatever rules may be necessary to preserve order and regularity in his class and will gladly assist him in enforcing such rules, still we submit that he has not the power to make any regulation such as the present which tends to deprive a great portion of his students of that instruction which they have *a right* to demand. That though such a rule might be enforced in a College where all the students reside on the premises, such rigid punctuality ought not to be demanded in a College in which not a single student resides, and to which many have to come from a very great distance to attend their several Lectures.

⁷⁷ Roscoe, *op. cit.*, (67), 26.

⁷⁸ Ranyard, *op. cit.*, (70), 115.

We further submit to the Senate that such a regulation is unjust in its principle pressing with equal severity on the inattentive and on the attentive, for even the most diligent cannot always be punctual, and by this new regulation if he be but a few minutes late he is to be deprived of the benefit of his Lecture, and the Senate need not be reminded that the loss of a single Lecture may be of serious importance to a Student in his future examinations. Besides it should be remembered that such rigid punctuality ought not to be demanded from the Students when even the Professors themselves are not always regular being frequently upwards of five minutes beyond the time fixed for the commencement of the Lecture. That the weather or a thousand other circumstances might detain a Student a few minutes beyond his time and that clocks almost always differ.

... We beg further to state, that in our opinion it would be the interest of the College, and the Professors, that there should be no rule such as the present, which would deter a large body of the Students from entering the class, that no such regulation exists in Kings College, and that several Students have already declared their intention if the rule is persisted in, to leave this College and to join the classes at Kings College.

... We therefore humbly pray, that the Senate will take into their immediate consideration whether *by the laws existing at present*, a Professor has the power of making any such regulation, and if it seems that he has, whether it is expedient, beneficial, or just, that such a rule should be enforced by any Professor at least during the present session.

Signed Ja^s Baldwin Brown
Colman M. O'Loghlen.⁷⁹

The majority of the mathematical classes seem to have supported this objection, a further petition featuring the signatures of no fewer than seventy-three students, including Charles Hargreave and Jacob Waley. Other less disciplined forms of protest also ensued: "A few enterprising youths kicked and knocked at the door, trying to burst it open, but on the appearance of a policeman, and a threat of 'the Council,' which might mean removal, they were brought to order."⁸⁰ Curiously, no official information exists on the eventual outcome of this minor controversy, and it is not known whether De Morgan's new rule was maintained or withdrawn once he had made his point. What is certain is that this was not the last time he came into conflict with his students on this matter, as evinced by an entry in Walter Bagehot's diary for 1844:

⁷⁹ UCC, No. 4266, Petition to Senate from James Baldwin Brown and Colman O'Loghlen, [22 March 1838].

⁸⁰ S. E. De Morgan, *op. cit.*, (5), 101.

Mr. De Morgan has lately had an amusing feud with one of his lower classes. Some students would come late, and the professor, to keep them out, locked the door, which has made him rather unpopular. It is not so bad as last year, however, when he told the same class with much bitterness, that they were robbing their parents and insulting him! The rest of the students thought of asking him to take the Chair of Rhetoric in consequence.⁸¹

Twenty years later, as De Morgan approached the age of sixty, his irascibility was still in evidence, indeed possibly more so. Someone who was able to observe the Professor as his career neared its close was James Bourne Benson, who, as the following extract will illustrate, was not a keen mathematician. Nevertheless, as a student in the mathematical classes between 1864 and 1866, his account, though brief, remains a valuable - and possibly unique - source, being possibly the latest description by a student of study under De Morgan. As such, it enables us to form a picture of the students' perception of his somewhat intimidating character in his later years. Moreover, it shows that while his abruptness of manner may have perhaps increased with age, De Morgan's painstaking commitment to his pupils' welfare remained unaltered.

De Morgan was irritable. Irritability of a Professor excites undergraduates to provoke it. They did. "Boys will be *boys*; no", said De Morgan, "*boys will be men*", and he made no allowances. Mathematics cannot tolerate a mistake. If you're not right, you're wrong. No one can say of mathematics, as of literature, that it is the wine that makes glad the heart of man. But if De Morgan's humanity, I use the word in its classical sense, was sometimes veiled in his lecture room, it was revealed by his dealings with the exercises of his pupils. If an exercise was worth notice, De Morgan wrote across the corner, "Show me." "Show me" meant 5 or 10 minutes with the Professor alone. In those occasional 10 minutes, if I did not gain more positive knowledge than from his lectures, I gained access to the Professor's heart, as he did to mine.⁸²

We now have a reasonable idea of the principal characteristics of the professor who lectured mathematics to all these young men over a period of more than a third of a century. However, we have yet to see their recollections of what he actually taught them. It will be recalled that sections 4.2.1-5 of the last chapter provided an analysis of the mathematical syllabus and the material covered by De Morgan in his lectures and mathematical tracts. What now remains is to examine not only what the students themselves were learning, but also how demanding they found the mathematical

⁸¹ Emilie Isabel Barrington, *Life of Walter Bagehot*, (London: Longmans & Co., 1914), 124.

⁸² Benson, *op. cit.*, (66), f.3.

course of study as taught by De Morgan. Obviously, this is a much harder task since student-authored documentation of such information is far from plentiful. However, there are three prime sources which do give a moderate idea of the average student workload during this period.

Two of these sources are extracts from the private writings of eminent students, dating from their respective periods of study at University College. However, it is the third which is perhaps the most valuable, for two reasons. Firstly, because it was written by a student whose ability seems to have been slightly more average than those who have been mentioned hitherto; and secondly, because it is an original college notebook kept by the student in which he transcribed the lectures of the Professor as they happened. This student was one John Golch Hepburn, who attended De Morgan's lower senior class in the 1846-47 session, being not only comparatively academically undistinguished while at college,⁸³ but also destined to achieve no particular eminence following his graduation.⁸⁴ However, as a historical source, Hepburn's notebook is particularly important since it provides us with a unique insight as to what the student would have experienced in De Morgan's lecture room 150 years ago.

The manuscript contains notes from twenty-one of De Morgan's lectures on algebraic geometry and the differential calculus, delivered between 11 March and 13 May 1847. The first, numbered 56, begins with a study of the ellipse, considering aspects such as area and conjugate diameters. Lecture 57 on 13 March, deals with Kepler's Laws, orbit-time calculations and an introduction to the parabola, with hyperbolae and asymptotes being discussed five days later. By 27 March, the emphasis was on tangents and chords to conic sections, following which Hepburn seems to have been absent from two or three lectures. His notes resume on 16 April, after the Easter vacation, when sections of cylinders, cones and spheres were under discussion. Less than a week later, following a brief consideration of stereographic projection on 20 April, the students were being introduced to the differential calculus.

De Morgan clearly approached the new subject at some considerable speed since, on its first day, he was teaching derivatives of fundamental expressions and the product and quotient rules, yet, by 24 April, two days later, he was considering examples such as $\frac{d}{dx}(x^x)$. By the end of the month, physical notions such as velocity had been

⁸³ He achieved joint seventh place in the examination for De Morgan's lower senior class in 1847 - *University College, London. Faculty of Arts and Laws. Distribution of the Prizes and Certificates of Honour. Session 1846-47*, (London: Taylor and Walton, 1847), 16.

⁸⁴ He does not appear to have proceeded to Oxford or Cambridge, for example.

introduced, with tangent/normal and max/min problems brought in on 1 May. That day had also seen De Morgan proceed to Maclaurin's theorem, which was proved for convergent series in the following lecture. Taylor's and Lagrange's theorems came next, together with related problems. By 8 May, the class had been introduced to the calculus of finite differences, the notes concluding with an introduction to the calculus of operations which followed a few days later.

In addition to what we have already seen in chapter 4, this text provides us with yet more valuable data concerning De Morgan's teaching. Reference to section 4.2.4 confirms that Hepburn's notes correspond very closely to topics dealt with in De Morgan's tracts for his lower senior class, but perhaps the most immediate impression one receives from examining this document is how rapidly De Morgan's students were propelled through the subject by their professor. His introduction to the calculus can be seen to take him a little over two weeks, consisting of just seven lectures. In that time, he discussed first principles, including foundational concepts such as limits, as well as derivatives of functions, fundamental rules and elementary applications, before moving on to some crucial results in analysis. It is little wonder that he provided tracts for his students to supplement their lecture notes!

In addition to the rapidity at which his lectures seem to have proceeded, the problems he set for homework were numerous and far from trivial. Furthermore, given that each lecture contains an average of three or four such questions, and that there were three lectures per week, we can safely assume that mathematics would have occupied a substantial proportion of the students' hours of study. A few examples from Hepburn's lecture notes will provide an indication of the standard of De Morgan's homework questions at the lower senior level:

Determine area of parabola as extreme case of area of ellipse.
Suppose axis major becomes $> \& >$; e being nearer $\&$ nearer $= 1$.⁸⁵

Prove whenever a fn becomes ∞ its diff^l Coeff^t becomes ∞ too.⁸⁶

Required the [Maclaurin] developments of ϵ^{ax} , $(1+x)^n$, $\sin x$, $\cos x$, $\tan x$, and $\epsilon^{\cos x}$ to 8th power at least.⁸⁷

⁸⁵ University College London Archives, MS.ADD.5, "Lectures on Algebraic Geometry and the Calculus delivered in University College, London, by Prof. A. De Morgan. Session, 1846-1847", f.25.

⁸⁶ *ibid*, f.189.

⁸⁷ *ibid*, f.193.

Try to give a geometrical proof of the ratio of two magnitudes wh^h
vanish is the same thing as the ratio of their diff. Coeff^{ts}.⁸⁸

In addition to such problems, Hepburn's notes are permeated with references to recommended reading, mainly comprising of relevant selections from De Morgan's many contributions to the *Penny Cyclopædia*, including the articles Map, Chart, Projection, Mercator's Projection, Induction, Fluxions, Differential Calculus, Taylor's Theorem and Operation. Perhaps the most intriguing citation, contained in the lecture on the foundations of the calculus, was "See *Leipzig Acts* 1684",⁸⁹ although no evidence exists to confirm that any student actually did! Thus it would certainly appear from this text that De Morgan's course was not for the faint-hearted, yet perhaps the only detail absent in the document is any indication of how difficult the student actually found it. It is for this information that we are obliged to refer to our two remaining sources, which fortunately shed some considerable light on this question.

These two sources are the diaries and correspondence of Walter Bagehot and Stanley Jevons, edited and published after their respective deaths. From both accounts it would appear that, with respect to both the complexity of the material and the amount of work which was required, mathematics under De Morgan was stimulating but never easy. Even his brightest pupils (and Bagehot and Jevons were among the ablest) had to struggle to keep up. Thus we find Bagehot writing in 1843: "De Morgan has been taking us through a perfect labyrinth lately; he was quite lost by the whole class for one lecture, but we are, I hope, getting better, and more gleg⁹⁰ at the uptake. We have been discussing the properties of infinite series, which are very perplexing."⁹¹ His account to his father of his revision in preparation for his B.A. examination is also enlightening as to the study methods necessary for distinction at this time:

I am principally engaged on Pure Mathematics at present, and am going over carefully all the necessary ground - I am going rather slowly perhaps, but I do not wish to leave any enemies in my rear. It is best, of course, to take the Pure Mathematics before the applied, since unless you know a science well applications will certainly be obscure. After I have finished the Pure Mathematics, I shall read the classical books thoroughly, and then go on to the Natural Philosophy, that is to say to the applied Mathematics. Of course I shall also read the Physiology, Logic, etc., but the main contention and difficulty is in

⁸⁸ *ibid*, f.197.

⁸⁹ *ibid*, f.137.

⁹⁰ i.e. astute, quick, keen, alert.

⁹¹ Barrington, *op. cit.*, (81), 118.

the other, and therefore I thought you would like to know the order in which I had taken the subjects. I took the classics in the middle for the sake of the variety which will be refreshing. I have been reading some of the Theory of Numbers, which De Morgan says is the best exercise for the head possible, and certainly is a hard stretch for my reading powers and memory.⁹²

Stanley Jevons experienced De Morgan's teaching at a later period than Bagehot, and during two separate intervals. However, like Bagehot, he too found the material covered in mathematics far from straightforward and his considerable academic achievements were only achieved through intense and conscientious study. These are recorded in considerable detail in the diary and correspondence written by him during his college years. It is thus in his memoirs that perhaps the fullest and most candid account of experiences as a student of De Morgan can be found. Indeed, so informative are some of the entries concerning his mathematical studies that, rather than summarising their content, the most effectual way to employ them is to quote an illustrative selection as an evocative description of one man's experience of mathematics at University College under the tuition of Augustus De Morgan.

23 October 1852: I am now fairly at work again for my last session, and shall try to get through a good deal of work, but rather with the intention of enabling myself to go on easily afterwards than of finishing up. During the first week and a half I had only chemistry, but though this took very little time, I got through little else, except reading the first three chapters of De Morgan's *Trigonometry*, and a few other things.... In reading difficult mathematical things I found that the best way to make them out was to go over them very carefully for two or three days together, instead of puzzling yourself for several hours to understand one sentence or one mathematical transformation. ...[On the 16th] I attended De Morgan's higher junior, and had the usual lecture on our necessary notions of ratio, with which he always begins. Professor Potter in the afternoon gave us an introductory lecture on Force, as the universal agent, as in motion, heat, electricity, chemical action, etc. I also began the long job of copying out De Morgan's tracts, with those on ratio. I intend to do them all, as they come out in my classes, because I think that whenever I work at any of the subjects again I shall miss them very much; I also intend to have all De Morgan's books.⁹³

31 October 1852: I have been working steadily all this week at college. I have worked full nine hours a day, chiefly at mathematics, which I get to like more as I attend to it better. We have just finished

⁹² *ibid*, 159.

⁹³ Harriet Ann Jevons (ed.), *Letters and Journal of W. Stanley Jevons*, (London: Macmillan & Co., 1886), 22-23.

what we are to do at present of double algebra and series, which I think rather interesting though hard. In the higher junior class we have been at ratio and fractions. I have finished copying out the four tracts on ratio and the one on series.⁹⁴

7 November 1852: I have little to put down this week, for I have done little but work quietly at college, mathematics chiefly, and we have been doing series - the binomial theorem and logarithmic series. In the higher junior we have just finished off the fifth book of Euclid. I never feel satisfied with my knowledge of anything unless I have gone over it connectedly and systematically, and so I am writing out the fifth book, shortly but distinctly, with De Morgan's proofs.⁹⁵

23 January 1853: ...As to college affairs, I am going on steadily and just as usual. In mathematics we are just beginning the theory of equations, and during the last week have got through Descartes', Fourier's, and Sturm's theorems of the limits of the roots of equations. They are the most truly difficult things we have come to, and I do not thoroughly understand them yet.⁹⁶

27 February 1853: I had hoped that when we began algebraical geometry, as we have done now, we should have had a little rest in mathematics, but the exercises seem only to get harder and harder.⁹⁷

29 January 1854: During the last two months at college I attended chiefly of course to the laboratory, though working at Potter's and trying to keep up in De Morgan's. ... I worked up well for Potter's examination, not keeping merely to what was sufficient to get the prize; and having De la Rue's electricity, I learned much more on that subject than was necessary. I had no difficulty with the mechanics, sound, light, electricity, except a little I missed in hydrostatics and a mistake or two about telescopes, but was not so much up in astronomy - a newer subject to me. On waves I answered a good deal. Mathematics was a much harder affair, of course. Some time before the examination I formed some desperate resolutions as to the place I would get, and I did work up a little. I tried very hard in the examination, but spent too much time on the hard ones, and came out fourth.⁹⁸

15 October 1859: I have only been at the college two days as yet, and feel rather strange. I have entered senior Greek and Latin, higher and lower senior mathematics, and senior German, in company throughout with Tom.⁹⁹ This is a rather difficult enterprise on my

⁹⁴ *ibid*, 23.

⁹⁵ *ibid*, 25-26.

⁹⁶ *ibid*, 29.

⁹⁷ *ibid*, 32.

⁹⁸ *ibid*, 36.

⁹⁹ His younger brother.

part, since I was in none of these classes before except lower senior mathematics, while it is seven years since I was in Latin or Greek. De Morgan has started right away in differential calculus. I think it would be impossible for me to keep up if I had not Tom's assistance, he having attended senior Greek and Latin last year.¹⁰⁰

27 January 1860: I find the classes at college a little dull - the charm is rubbed off a few things; but then one learns more and more to adore De Morgan as an unfathomable fund of mathematics. We were delighted the other day when, in the higher senior, he at last appeared conscious that a demonstration about differential equations, which extended through the lecture, was difficult; he promised, indeed, to repeat it. But then one is disappointed to find that the hardest thing he gives in any of his classes is still to him a trifle, and that the bounds of mathematical knowledge are yet out of sight.¹⁰¹

28 November 1860: I am now attending college again regularly. My classes are De Morgan's higher senior mathematics, Potter's senior mathematical natural philosophy, Malden's extra Greek class, and Mr. Martineau's mental philosophy class in the Manchester New College, which is close at hand in University Hall. I am, of course, better up to De Morgan's brain-rackings this session, and shall devote much time to mathematics, yet, from having no natural talent for figures or quick memory, have no hope of becoming a practical mathematician. Besides, it is somewhat late in the day at twenty-six to learn mathematics, with which you will succeed from the first or never.¹⁰²

As has been mentioned, Jevons was later to acknowledge the profound effect of De Morgan on his intellectual development. It is clear also that the careers of many other former students were influenced in some way by De Morgan's teaching; indeed, four of them later returned as professors to University College. But De Morgan's influence does not seem to have extended much further than this. For example, with the possible exception of Todhunter's textbooks, we do not see his pupils attempting to emulate his teaching in any way. Indeed, somewhat ironically, E. J. Routh, himself a product of the progressive methods both of the masters at University College School and De Morgan, later became one of the staunchest defenders of the Cambridge Tripos system so heavily criticised by his erstwhile professor.

Yet while for one so universally revered, De Morgan appears somewhat bereft of disciples willing to propagate his ideas and methodology, there remains to this day a by-product of his teaching which provides a tangible legacy to his influence, albeit

¹⁰⁰ H. A. Jevons, *op. cit.*, (93), 148.

¹⁰¹ *ibid*, 150.

¹⁰² *ibid*, 155.

indirectly. This was a society devoted entirely to the reading and publication of mathematical research which would soon become the first mathematical society in Britain to boast a nationwide membership. It is perhaps fitting that the creation of this new body came at the very end of De Morgan's long career at University College, by which time he had become one of the most respected mathematicians in the country. However, as will be seen, although it would be wrong to underplay his part in its foundation, his role was more to encourage and influence its early life than to provide the impetus for its creation.

5.2 The Foundation of the London Mathematical Society¹⁰³

5.2.1 Background

Throughout the nineteenth century in Britain, as elsewhere in Europe, the unprecedented specialisation of science was reflected in a growing dissatisfaction with the established scientific societies. The Royal Society, founded in 1662 to encourage research in the natural and physical sciences, had come under severe criticism from prominent scientists for its monopolistic position. The need was felt for more specialist outlets for the increasingly divergent branches, resulting in the foundation of the Geological Society in 1807, followed by the Astronomical Society in 1820, the Statistical Society in 1834 and the Chemical Society in 1841, as well as the British Association for the Advancement of Science in 1831.

For the British mathematician of the mid-nineteenth century, however, no national society existed. Whereas some sought solace in the Statistical Society, its priority was more with the *collection* of data than its mathematical analysis. More attractive by far was the Astronomical Society which, as mentioned in Chapter 3, included among its members such mathematicians as Charles Babbage, Sir John Herschel, Sir George Airy and, of course, Augustus De Morgan. Elsewhere, the Cambridge Philosophical Society (founded in 1819) certainly received mathematical papers, but mathematics was far from being its sole concern;¹⁰⁴ and, while the British Association had a mathematical section, it only met once a year, and, in any case, its agenda was entirely different from that of an academic society.¹⁰⁵

¹⁰³ This section is adapted from the following paper: Adrian C. Rice, Robin J. Wilson and J. Helen Gardner, From Student Club to National Society: The Founding of the London Mathematical Society in 1865, *Historia Mathematica*, **22** (1995), 402-421.

¹⁰⁴ A. Rupert Hall, *The Cambridge Philosophical Society. A History, 1819-1969*, (Cambridge: Cambridge Philosophical Society, 1969).

¹⁰⁵ Jack Morrell & Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science*, (Oxford: Clarendon Press, 1981).

This is not to say that England had been permanently bereft of societies devoted purely to mathematics. Long before the creation of the London Mathematical Society in 1865, such bodies had existed, such as the Manchester Society, founded in 1718, and the Oldham Society of 1794. Of greater renown than either of these was the famous Spitalfields Mathematical Society, which dated from 1717, and which took as its rule "if any member be asked a question in the Mathematics by another, he shall instruct him in the plainest and easiest method he can, or forfeit one shilling".¹⁰⁶ In his *Budget of Paradoxes*, De Morgan gave a charming account of their weekly meetings in Crispin Street, East London, noting "that each man had his pipe, his pot, and his problem".¹⁰⁷ The fact that smoking and drinking were permitted at meetings of the Spitalfields Society contrasts sharply with the more sober gatherings of its successor where, according to De Morgan, "not a drop of liquor is seen at our meetings, except a decanter of water: all our heavy is a fermentation of symbols; and we do not draw it mild".¹⁰⁸

Although it had been established as a club for the improvement of the studious artisan, especially the silk weavers of East London, membership of the Spitalfields Society is known to have included John Dollond (1706-1761), the renowned manufacturer of optical instruments, Thomas Simpson (1710-1761), mathematical writer and professor at the Royal Military Academy in Woolwich from 1743, and William Frend (1757-1841), De Morgan's friend, fellow mathematician and father-in-law. Another reputed member was Abraham de Moivre (1667-1754), although De Morgan thought it unlikely. Yet, during the nineteenth century, perhaps due to the decline in attendance of the working classes, the society's membership dwindled, until by the 1840s there were fewer than twenty members.

In 1845, the Society's members decided on dissolution and, rather than let their valuable library be lost, approached the Royal Astronomical Society to consider incorporating it with their own. De Morgan served on the committee appointed to inspect the old society, reporting to Herschel that it had quite changed from its clay and pewter days: "We found an FRS, an F.Ant.S, an F.Linn.S, a barrister, two silk manufacturers, a surgeon, a distiller, &c.;...Their library is a good one."¹⁰⁹ The committee recommended that "the books, records, and memorials of the

¹⁰⁶ J. W. S. Cassels, The Spitalfields Mathematical Society, *Bulletin of the London Mathematical Society*, 11 (1979), 241-258, p.244.

¹⁰⁷ Augustus De Morgan, *A Budget of Paradoxes*, (London: Longmans, Green, and Co., 1872), 232.

¹⁰⁸ *ibid*, 236.

¹⁰⁹ Royal Society Herschel Archives, MS.HS 6.222, De Morgan to Sir John Herschel, 19 May 1845.

Mathematical Society should be made over to the Astronomical Society [and] that all the members of the former society not already Fellows of this Society should be thereupon elected Fellows without payment of any contribution whatsoever".¹¹⁰ In June 1845, the old mathematical society ceased to exist.

For the next twenty years, the two major English outlets for the mathematician were the Royal Society and the Cambridge Philosophical Society. This latter might have seemed a good starting point for the formation of a sister mathematical society, since Cambridge was, at this time, the foremost place for mathematical instruction in the country. However, there does not seem to have been an adequate number of those sufficiently motivated or interested in forming such a body. London had many more practising mathematicians, not only academic ones, and was clearly at an advantage; so, while it was by no means *inevitable*, it is not surprising that when a new society was formed, it came into being in the capital. Nor is it particularly incredible that University College was the place of its foundation, De Morgan's influence making that institution the centre of mathematical learning in the metropolis. What *is* remarkable, however, is that it arose from the efforts, not of De Morgan himself, nor of any mathematician of note, but of two of his pupils, Arthur Cowper Ranyard (1845-1894) and the Professor's own son, George Campbell De Morgan (1841-1867).

Only twelve years old when his association with University College began, Ranyard attended University College School between 1857 and 1860, graduating to the college itself for the next four years. There, he became good friends with his fellow schoolmate George De Morgan, as well as attending the Professor's lectures. These encouraged Ranyard to further his study of mathematics and astronomy. In 1863, at the age of 18, he was elected a Fellow of the Royal Astronomical Society, and entered Pembroke College, Cambridge, two years later. More of an astronomer than a mathematician, he is best remembered for his observations of solar eclipses and for a long series of astronomical articles for the scientific journal *Knowledge*, of which he was the editor from 1888.¹¹¹ In fact, according to a colleague, "he seems to have ceased to take an interest in the [Mathematical] Society very soon after it was actually founded. He was a very active member of the Council of the Astronomical Society [1872-88 & 1892-94]...; but I never heard him mention our Society".¹¹²

¹¹⁰ *Monthly Notices of the Royal Astronomical Society*, 7 (1846), 51.

¹¹¹ W. H. Wesley, Arthur Cowper Ranyard and his work, *Knowledge*, 1 February 1895, 25-27.

¹¹² J. W. L. Glaisher, Notes on the early history of the Society, *Journal of the London Mathematical Society*, 1 (1926), 51-64, p.61.

A more thoroughly committed mathematician was George Campbell De Morgan. The third child of Augustus and Sophia De Morgan, he too had gone to University College School (1856-7) and thence to the college where he had gained numerous distinctions, winning the first prize in his father's class, a valuable scholarship, and the University of London gold medal when he took his M.A. in 1863. From 1863-65, he was a mathematics master at the school, also examining in mathematics for the University of London. Nicknamed "the younger Bernoulli",¹¹³ in reference to the fact that his father too was an able mathematician, George's health was never strong. He read one paper to the London Mathematical Society, 'On the development of a certain class of Functions', on 13 December 1866, but was not destined to live long enough to present another.

5.2.2 The Society's inception

The classic (and original) account of the formation of the London Mathematical Society is given by Sophia De Morgan in her *Memoir* of her husband. The story goes that, sometime in the summer of 1864, the younger De Morgan and Ranyard were "discussing mathematical problems during a walk in the streets, when it struck them that 'it would be very nice to have a Society to which all discoveries in Mathematics could be brought, and where things could be discussed, like the Astronomical' ".¹¹⁴ The quotation was very probably Ranyard's, being a Fellow of the Royal Astronomical Society and thus having first-hand experience, but the sentiment clearly belonged to both. In any case, "it was agreed between the young men that this should be proposed, and that George should ask his father to take the chair at the first meeting".¹¹⁵ In fact, it would seem that it was Ranyard who made this suggestion to the Professor since, in a letter to Ranyard dated 30 October 1864, George writes: "As it was you who asked him to preside, would you send a note reminding him of the date?"¹¹⁶

Enlisting Augustus De Morgan's support for their venture was easy; it was the name of the new Society which was to cause problems. The tentative title agreed between the two friends was 'The London University Mathematics Society', but the Professor apparently objected to this, although his grounds are not known; however, a circular, lithographed from George De Morgan's handwriting and sent to mathematicians all over the country, reads as follows:

¹¹³ MacFarlane, *op. cit.*, (23), 23.

¹¹⁴ S. E. De Morgan, *op. cit.*, (5), 281.

¹¹⁵ *ibid.*

¹¹⁶ *Proceedings of the London Mathematical Society*, (1), **26** (1895), 554-557, p.554.

University College,
Gower Street, W.C.
Oct. 10, 1864.

Sir,

We beg leave to request the honour of your attendance at the first meeting of the 'University College Mathematical Society', which will be held at the College in the Botanical Theatre on the evening of the 7th of November, at eight o'clock precisely.

Professor De Morgan has promised to take the chair, and will give an introductory address, and the general objects and plans of the Society may then be discussed.

It is proposed that the ordinary meetings of the Society should take place once a month, and that the papers then read should be lithographed and circulated among the members.

The annual subscription will not exceed half a guinea.

We have the honour to be, Sir,
Your obedient servants,

G.C. De Morgan
Arthur C. Ranyard

Hon. Secs.
*pro tem.*¹¹⁷

Among the recipients of this letter was Thomas Archer Hirst, until recently the mathematics master at University College School. If De Morgan's initial involvement with the London Mathematical Society played a role in attracting members, Hirst, through his many friends and contacts in the British scientific community, was to ensure strong and continued support for the Society throughout its early years. As they discussed their new project, George De Morgan noted to Ranyard: "I think he [Hirst] will be an important member, and may take an interest in the affair".¹¹⁸ It was a more than accurate prediction!

No official records exist of the meeting of 7 November 1864, but we can be sure that it did take place since Hirst recorded his attendance in his diary.¹¹⁹ As to the size of the meeting and who else attended, the information is less certain. For example, in his centenary article 'A Century of the London Mathematical Society', Sir Edward Collingwood states that Professor De Morgan was absent through ill-health and two

¹¹⁷ University College London Archives: London Mathematical Society Papers (hereafter LMS Papers), George Campbell De Morgan and Arthur Cowper Ranyard to Thomas Archer Hirst, 10 Oct. 1864.

¹¹⁸ *op. cit.*, (116), 555.

¹¹⁹ William H. Brock and Roy M. MacLeod (eds.), *Natural Knowledge in Social Context: The Journal of Thomas Archer Hirst, F.R.S.*, (London: Mansell, 1980), 1706.

days later was writing to Ranyard for an account of its proceedings.¹²⁰ However, in his contemporary record, Hirst notes that at the meeting, "De Morgan gave an address, which I seconded".¹²¹ Moreover, the Society's obituary notice of Ranyard implies that it was *George* De Morgan whose health had prevented his appearance, not his father.¹²² This is highly likely, considering the delicate state of the young man's constitution at this time. So, from these tantalising snippets of information, we can surmise that Professor De Morgan, Hirst and Ranyard definitely attended on 7 November. But the question of who else was there remains a mystery.

Similarly, we can only speculate as to what was discussed. Presumably, being a preliminary meeting, business would have included such matters as finance, the formulation of rules and membership criteria, subscriptions (initially ten shillings per annum), the election of a committee, and the Society's name. On this last point we can be certain that major changes were resolved. Members such as Thomas Hirst and Philip Magnus (1842-1933), another mathematics teacher at the School and former pupil of De Morgan's, were concerned that the title 'University College Mathematical Society' would give people the impression that "the Society was only an upper higher senior class of De Morgan's".¹²³

There can be no doubt that Hirst played a major part in enlarging the scope of the Society's operations, although the Professor's role should not be underestimated. Paying tribute to him in 1871, Hirst took care to stress that "it was Mr. De Morgan who further did away with the original restriction of membership to persons associated with University College".¹²⁴ Whoever bore the final responsibility for this decision, it resulted in one further significant change: when they met for their inaugural meeting at University College on Monday 16 January 1865, it was as the London Mathematical Society.¹²⁵

¹²⁰ Edward F. Collingwood, A century of the London Mathematical Society, *Journal of the London Mathematical Society*, **41** (1966), 577-594, p.578.

¹²¹ Brock & MacLeod, *op. cit.*, (119), 1706.

¹²² *op. cit.*, (116), 555.

¹²³ *ibid.*

¹²⁴ *Proceedings of the London Mathematical Society*, (1), **3** (1871), 233.

¹²⁵ It is perhaps worth mentioning as an aside that, whatever the formal name of the Society may have been, it would be very wrong to assume that it was universally known as 'The London Mathematical Society'. Although that title invariably appeared in all official communications, in conversation, correspondence and outside publications, it was referred to simply as 'the Mathematical Society' until well into the present century. This abbreviation ultimately gave way to the familiar 'L.M.S.' in current usage. Although we cannot say exactly when, it is unlikely that this present colloquial title could have emerged until sometime after the Second World War since it would have been easily confused with the railway company with the same initials which operated until 1948!

5.2.3 The first year

The inaugural meeting began at eight o'clock with the election of Augustus De Morgan and Thomas Hirst as the Society's first President and Vice-President, respectively. The Society's founding Secretaries were Henry Mason Bompas (1836-1909) and Herbert Hardy Cozens-Hardy (1838-1920), both former pupils of De Morgan at University College and both practising lawyers; the latter to become a distinguished high court judge and, later, Master of the Rolls. It is not known why neither Ranyard nor George De Morgan were elected to these posts, but possible reasons may be attendance at Cambridge in the case of the former and the poor health of the latter.

Following these elections, the President then gave a very idiosyncratic opening address in which he laid down what were, in his opinion, the correct aims of a mathematical society, the prime object being "the cultivation of pure Mathematics and their most immediate applications".¹²⁶ He also expressed a hope that the Society would not become dominated by one particular field of study, but that every branch would have ample support among its members. Finally, he suggested four neglected areas of study which would, he believed, facilitate future mathematical research;

- "what may be called Logical Mathematics"¹²⁷ - that is, the connection between logic and mathematics;
- the history of mathematics;
- the limitations of language in mathematical problems; and
- the simplification of proofs by simple common sense, where possible.

He concluded that "If it should chance that we find a disposition among the members of this Society to leave the beaten track and cut out fresh paths, or mend the old ones, we may make this Society exceedingly useful".¹²⁸

The venue of the meeting was an appropriate one, for the Society's rejected title of 'University College Mathematical Society' was still more accurate at this stage; of the twenty-seven founding members, no fewer than twenty-six were, or had been, associated in some way with the college, the school, or both, as shown in Table 1. Even discounting De Morgan and Hirst, all but two of the remaining members were

¹²⁶ Augustus De Morgan, Speech of Professor De Morgan, President, at the first meeting of the Society, January 16th, 1865, *Proceedings of the London Mathematical Society*, (1), 1 (1865-66), 1-9, p.1.

¹²⁷ *ibid*, 4.

¹²⁸ *ibid*, 9.

Table 1

Members of the London Mathematical Society at its formation

1.	Augustus De Morgan	
2.	Thomas Archer Hirst	
3.	Samuel Newth	UCL: BA 1841, MA 1842
4.	William Watson	UCL: BA 1846
5.	Henry Mason Bompas	UCL: MA 1857, LLB 1862,
6.	Arthur Cowper Ranyard	UCS 1857-60, UCL 1860-4
7.	David Lindo Alexander	Trinity Hall, Cambridge 1860-4
8.	George Campbell De Morgan	UCS 1856-7; UCL: BA 1862, MA 1863
9.	Philip Magnus	UCS 1854-8; UCL: BA 1863, BSc 1864
10.	Herbert Hardy Cozens-Hardy	UCL: LLB 1863
11.	William Jardine	UCL: late 1850s
12.	Benjamin Kisch	UCL: BSc 1862, MA 1863
13.	Marcus Nathan Adler	UCS 1852-3; UCL: BA 1857, MA 1859
14.	John Bridge	UCL: MA 1852
15.	Numa Edward Hartog	UCS 1857-61; UCL: BA 1864
16.	John Freeman Norris	UCL: Matric. 1861
17.	Framjee Rustomjee Dasai	UCS 1861-3; UCL current student
18.	Samuel Noble Bruce	UCL: Matric. 1853
19.	Frederick Toplis	UCS 1856-63
20.	Edward Henry Busk	UCL: MA 1864, LLB 1866
21.	Edwin Waterhouse	UCL: BA 1860
22.	William Desse	UCS 1864-5; UCL current student
23.	Henry Selfe Page Winterbotham	UCL: LLB 1859
24.	Edward John Routh	UCS 1844-6; UCL: BA 1849, MA 1853
25.	Horatio Nelson Grimley	UCL: BA 1862
26.	Robert Bellamy Clifton	UCL: early 1850s
27.	Lewis Solomon	UCS 1862-3; UCL current student

students or alumni of the college. Indeed, ten had connections with the School either as teachers or ex-pupils, five having attended when Hirst was mathematics master.¹²⁹ The fact that only one founder member could claim complete independence from the teachings of Hirst or De Morgan further rendered the appellation '*London Mathematical Society*' something of an exaggeration.

¹²⁹ Temple Orme, *University College School, London. Alphabetical and Chronological Register for 1831-1891*, (London: H. Walton Lawrence, 1892).

It is also interesting to note that many early members of the London Mathematical Society had been actively involved with other student societies at University College, including Bompas (President of the Debating Society, 1862-3), Cozens-Hardy (President of the Reading-Room Society, 1862-3; and also of the Debating Society, 1863-4), and Magnus (Vice-President of the Literary and Philosophical Society, 1863-5). Mathematics was certainly not the sole field of study for founder members. In addition to Bompas and Cozens-Hardy, several had - or were in the process of receiving - a legal training; namely, De Morgan, Alexander, Jardine, Busk and Winterbotham. So it would seem that a fair proportion of the initial membership may have been motivated to join by a purely extra-curricular interest in mathematics.

Despite this apparent bias towards University College, however, many members had received tuition elsewhere, exactly one-third being Cambridge men. Eight of these were wranglers: De Morgan (4th, 1827), Routh (1st, 1854), Bompas (5th, 1858), Clifton (6th, 1859), Alexander (30th, 1864), Jardine (22nd, 1864), Grimley (12th, 1865) and Hartog (1st, 1869).¹³⁰ Yet, even at this formative stage, not every member was based in London. Routh, it will be recalled, was, by 1865, firmly established as a Tripos coach in Cambridge. Similarly, Clifton was shortly to move from his professorship in Manchester to a new post in Oxford. Thus, outside support for the London Mathematical Society was in existence from the very beginning.

The necessity of finding new members and increasing the Society's reputation by the publication of original papers was a matter of extreme importance during the early months of the Society's existence. In a letter to Hirst, dated two days after the inaugural meeting, Bompas expressed the hope that "if you meet any mathematician now you always ask him to join us".¹³¹ Less than two weeks later, De Morgan was writing: "The only way to get the papers printed is to get more members, and the only way to get more members is to get the papers printed."¹³² His presidential address became the Society's first published document, and membership rose steadily throughout the year from twenty-seven to sixty-nine.

The Society's first new recruit was Benjamin Gompertz (1779-1865). As President of the Spitalfields Society at its dissolution, Gompertz provided the link between London's old and new mathematical societies, being the only person to have been a member of both. A self-taught mathematician and actuary, he is most famous for his

¹³⁰ Venn, *op. cit.*, (26), 2, 275; 5, 367; 1, 313; 2, 68; 1, 28; 3, 552; 3, 158; 3, 273.

¹³¹ LMS Papers, Henry Mason Bompas to Thomas Archer Hirst, 18 Jan. 1865.

¹³² *op. cit.*, (116), 556.

law of human mortality. Highly valued in the actuarial profession, "had this principle been propounded in the days of Newton," wrote De Morgan, "vitality would have been made a thing of, like attraction."¹³³ It seems somehow fitting that Gompertz was the first member to feature in the Society's obituary, dying before it was fully one year old.

It was not long before the Society attracted the biggest names in contemporary English mathematics. Arthur Cayley, James Joseph Sylvester and William Spottiswoode (1825-1883) were elected on the same day in June 1865, all proposed by Hirst. Cayley, who had been elected Sadlerian Professor at Cambridge two years previously, already had over two hundred papers to his name and was to contribute to almost every area of pure mathematics, especially invariant and covariant theory, matrices, group theory and geometry. He wrote to Hirst four days before his election: "I shall really be very glad to join the London Mathematical Society; it has always appeared to me that something of the kind was a desideratum; and tho' I cannot do it so much as if I had been still in London, I will certainly try to take part in the proceedings; I shall therefore be much obliged if you will propose me as a member."¹³⁴ He was certainly true to his word, becoming one of the Society's most active members, and its President from 1868-70.

Cayley's first paper for the Society on 'Transformation of plane curves' was read on 16 October 1865; seventy-seven others were to follow! However, as another early member J.W.L. Glaisher later reported: "Cayley regarded the reading of a paper merely as a formality preparatory to its being printed. Nevertheless, he stated the main features of his paper clearly and at a suitable length, but he confined himself strictly to the contents of the paper, so that it conveyed little information to those not already acquainted with the subject. It was a bare statement of methods and results."¹³⁵

Like Cayley, Sylvester had also written to Hirst expressing an early interest in the London Mathematical Society: "I shall be happy if you care about it to be made a member - or if you don't care about it, but think it right I should do so."¹³⁶ Keen to help the Society establish a high scientific reputation, he also announced a significant new result - his discovery of a demonstration of Newton's rule for finding the

¹³³ Augustus De Morgan, Obituary notice of Benjamin Gompertz, *The Athenæum*, No.1969, 22 July 1865, 117.

¹³⁴ LMS Papers, Arthur Cayley to Thomas Archer Hirst, 15 June 1865.

¹³⁵ Glaisher, *op. cit.*, (112), 61.

¹³⁶ LMS Papers, James Joseph Sylvester to Thomas Archer Hirst, 15 June 1865.

imaginary roots of algebraic equations. "If you can arrange for my doing so, I should have much pleasure in bringing it before the Mathematical Society of London about which you spoke to me some time back...You will wonder I think at the simplicity and at the same time elegance of the method."¹³⁷

This important result was presented on 19 June 1865, becoming the first mathematical paper to be published by the Society.¹³⁸ Elected its second president in November 1866, in succession to De Morgan, Sylvester wrote papers on applied mathematical topics such as the geometry of motion in addition to his work on the theories of number and algebraical form, sharing with Cayley the credit for the development of invariant theory. But, according to Glaisher, he did not share Cayley's style of communicating his research: "whatever he was engaged upon at the moment, even if it could have been set as a Tripos problem, seemed to him to be of supreme interest and importance; and in describing work of his own he was often carried away by his enthusiasm, and on one occasion in his excitement upset the blackboard and the easel."¹³⁹

Whereas Cayley and Sylvester were Cambridge-trained mathematicians, Spottiswoode had studied mathematics at Oxford and was also an enthusiastic physicist. In 1851, he had published the very first elementary treatise on determinants, but it was a series of memoirs on the contact of curves and surfaces in the Royal Society's *Philosophical Transactions* that made his reputation. At the time of his election to the London Mathematical Society, he was the president of the mathematical section of the British Association. In the London Mathematical Society, he succeeded Cayley to become the fourth President in 1870.

That three such eminent and gifted mathematicians were among the first to join such a new body illustrates the very high esteem in which De Morgan was held by his contemporaries, enabling the fledgling society over which he presided to develop and flourish so rapidly that, in only five months, its membership nearly doubled. Although some credit for this rise must go to reputation and word of mouth, many early members played a part in the recruitment effort. Between January 1865 and November 1866, George De Morgan and Ranyard each proposed five members, Professor De Morgan nominating four. However, even the most cursory glance at

¹³⁷ *ibid*, 11 June 1865.

¹³⁸ James Joseph Sylvester, An elementary proof & generalization of Sir I. Newton's hitherto undemonstrated rule for the discovery of imaginary roots, *Proceedings of the London Mathematical Society*, (1), 1 (1865-66), No.II.

¹³⁹ Glaisher, *op. cit.*, (112), 61.

the minute books reveals that the two most active members in this area were Hirst, who proposed nineteen new members, and Sylvester (himself proposed by Hirst), who proposed seventeen. The sharp rise in membership also illustrates the very real need which existed for a mathematical society at this time; such a scheme was clearly long overdue.

The final major figure to join the Society in its first year was Henry John Stephen Smith (1826-1883). A Fellow of Balliol College, Oxford, he was Savilian Professor of Geometry from 1860 until his death in 1883, when he was succeeded by Sylvester. Elected to the London Mathematical Society on the day of Cayley's first paper, Smith's presidency covered the period of 1874-76. His work covered geometry, elliptic functions and especially number theory which fascinated him. Described as the "greatest disciple of Gauss",¹⁴⁰ Smith made important advances in higher arithmetic, extending and generalising the former's work in this area. By all accounts, his verbal expositions were equally successful; Glaisher later wrote:

H.J.S. Smith was the best expositor of a mathematical subject I have ever heard....All that he said was distinguished by a graceful mode of expression, and ease and charm of manner; and there was often an added touch of wit or playful allusion to the politics of the day. He once said to me that the account of a paper on an advanced part of a subject ought to end where the paper begins; and he followed this rule himself, and explained simply and naturally the general lines of a subject until he had reached the point where he could in a few words indicate the nature of the research to which the paper related. It was therefore always possible to learn something valuable from his exposition of a paper, even when one had no previous acquaintance with the subject.¹⁴¹

De Morgan's influence may have given the Society much needed initial momentum, but it was papers by later Presidents such as Cayley, Sylvester, Spottiswoode and Smith that placed it on a level with other scientific societies.

The diversity of the members' backgrounds and interests led to a wide variety of topics being discussed at meetings. Each member had his own distinctive style of presenting a paper, reflecting his particular character, from the dignified aloof Hirst to the flamboyant excitable Sylvester. Table 2 indicates the range of topics presented at the early meetings. The quality of these presentations, however, was distinctly

¹⁴⁰ *D.N.B.*, 53, 52.

¹⁴¹ Glaisher, *op. cit.*, (112), 61-62.

Table 2
Papers Presented in 1865

16 January	
A. DE MORGAN	Opening Address*
A. C. RANYARD	On Determinants
20 February	
H. M. BOMPAS	Strictures on the Laws of Motion
T. A. HIRST	On Geometrical Inversion
20 March	
M. N. ADLER	Mr Gray's Method of forming Logarithmic Tables
10 April	
H. N. GRIMLEY	Mr Byrne's System of Dual Arithmetic
15 May	
A. DE MORGAN	Values of Annuities variously payable
W. JARDINE	An account of a proof of Pohlke's fundamental proposition of Axonometry
B. KISCH	A formula in the Theory of Combinations
19 June	
J. J. SYLVESTER	An Elementary Proof & Generalisation of Sir I. Newton's hitherto undemonstrated rule for the discovery of imaginary roots*
M. JENKINS	The regular Hypocycloidal Tricusp**
16 October	
A. CAYLEY	Transformation of Plane Curves*
20 November	
A. DE MORGAN	Proof of Euclid I.47, not involving the definition of a parallelogram
R. HARLEY	Differential Resolvents*
18 December	
R. TUCKER	On Radial Curves*
J. J. SYLVESTER	On Motion in a Circle, & its relation to Planetary Motion***
A. CAYLEY	Volume of Tetrahedron

* = published in the Society's *Proceedings*.
 ** = published in the *Mathematical Reprint of the Educational Times*, Vol. 4, p.58.
 *** = published in the *Philosophical Magazine* for 1866.

variable. As Hirst recorded in his diary for December 1865: "afterwards went to the Mathematical Society. The paper was by Tucker 'on Radial Curves' and was decidedly uninteresting. He spoke disconnectedly and still with apparent self-possession. The meeting would have been a decided failure if it had not been for Sylvester who gave us some very pretty new theorems on circular motion...."¹⁴²

5.2.4 The next year

The first Annual General Meeting was held on 15 January 1866. At this meeting, De Morgan "made some remarks upon the state of the Society", as is recorded in the Minutes: "He called attention to the novelty and importance of many of the papers, and remarked that this was the only society in England where such papers could be received. He also expressed his opinion that the objects of the Society had on the whole been well carried out by these papers, but recommended that readers of papers should keep within the comprehension of the majority of the hearers."¹⁴³

Some discussion also took place regarding the propriety of moving the Society away from University College to a more central location, with "Prof. Hirst stat[ing] his belief that the rooms of the Chemical Society would be lent if applied for".¹⁴⁴ However, "The President opposed removal on the grounds that the expense would be increased, and that the printing of papers would have to be given up. Mr. Spottiswoode stated that he had for some time acted as secretary of the Geographical Society, and that the President's estimate far exceeded the expenses of that Society."¹⁴⁵ It was therefore resolved "that steps be taken by the Committee to ascertain on behalf of the Society whether and on what terms rooms can be obtained at Burlington House".¹⁴⁶

This meeting saw the re-election of De Morgan as President, but when it came to the election of the Vice-President, a change was made, as Hirst noted in his diary: "I had previously proposed in the Committee that Cayley and Sylvester should be Vice-Presidents for the coming year. Instead of simply putting the Committee's recommendation to the meeting De Morgan proposed that I should remain a Vice-President. The proposition was warmly carried. I was taken by surprise and said nothing though I did not approve of three Vice-Presidents."¹⁴⁷ Despite his offering to

¹⁴² Brock & MacLeod, *op. cit.*, (119), 1766.

¹⁴³ The London Mathematical Society Minute Book, vol. I, 15 January 1866.

¹⁴⁴ *ibid.*

¹⁴⁵ *ibid.*

¹⁴⁶ *ibid.*

¹⁴⁷ Brock & MacLeod, *op. cit.*, (119), 1770.

step down, Hirst's fellow members refused to accept his resignation and the convention of having three Vice-Presidents was thereby created.

New members continued to arrive throughout 1866. George Salmon (1819-1904), professor of mathematics at Trinity College, Dublin, joined in April. A highly skilled geometer and algebraist, he was well known through books such as *Conic Sections* (1847), *Higher Plane Curves* (1852), and *Lessons Introductory to the Modern Higher Algebra* (1859), in which he incorporated recent results by Cayley and Sylvester with some of his own. On 18 June, seven new members were elected, including Stanley Jevons, Isaac Todhunter and William Kingdon Clifford (1845-1879).

Clifford was to be a major contributor to the Society's proceedings. Proposed by Ranyard and seconded by George De Morgan, he joined the Society while still a student at Trinity College, Cambridge. Hirst's diary for 22 November 1866 notes his first appearance, remarking that "he gave us a very good paper 'on Harmonics'....Clifford is the Lion of this season. Everybody is anxious to entertain him. I only hope his head will remain unturned."¹⁴⁸ As a result of the increase in membership, 1866 saw a wider variety of papers being presented than the previous year, as shown in Table 3, although those the Society actually published still remained in the minority.

Up to this point, despite its early changes of name and membership rules, the London Mathematical Society was still considered as a University College student society, along with the existing Medical, Debating, Reading-Room and Literary and Philosophical Societies. However, as an indication of how rapidly membership was expanding beyond the college, by the end of the year it had ceased to rank among such clubs,¹⁴⁹ as is documented in the *University College Gazette*: "Among University College Societies, the Mathematical Society, founded in 1863, or soon after, under Professor De Morgan as President, and Dr. T. Hirst as Vice-President, should not be forgotten. This Society soon attracted the notice of some of the foremost mathematicians of the country, and from being a University College Society it developed into the Mathematical Society of London and removed from the College to quarters of its own in 1867."¹⁵⁰

¹⁴⁸ *ibid.*, 1793.

¹⁴⁹ *The University College Calendar for the Session 1865-66*, (London: Walton and Maberly, 1865), 153; *The University College Calendar for the Session 1866-67*, (London: Walton and Maberly, 1866), 177; *The University College Calendar for the Session 1867-68*, (London: James Walton, 1867), 157.

¹⁵⁰ *op. cit.*, (1), 90.

Table 3

Papers Presented in 1866

19 February A. DE MORGAN T. COTTERILL	A Proof that every Function has a Root* Certain Properties of Plane Polygons of an even number of sides*
19 March M. W. CROFTON S. ROBERTS J. J. SYLVESTER	On certain properties of the Cartesian Ovals, treated by the Method of Vectorial Coordinates* On the Centres of Algebraical Curves and Surfaces** On an addition to Poinso't's Ellipsoidal Mode of representing the Motion of a Rigid Body turning freely round a Fixed Point, whereby the time may be made to register itself mechanically*
16 April A. CAYLEY A. CAYLEY T. COTTERILL A. DE MORGAN A. J. ELLIS T. A. HIRST T. A. HIRST	Correspondence of two Points on a Curve* Difference between two consecutive prime numbers can be made greater than any assigned number Property of a Certain Curve described on a Sphere Simple method of describing a small arc of a Curve, when the two extreme points, and the tangents at those points, are given Method of finding the Foci of an Ellipse, and drawing the curve, two conjugate diameters being given The number of Normals which can be drawn from a point to a Curve Remarks on Quadric Inversion
21 May A. DE MORGAN A. DE MORGAN M. JENKINS H. J. S. SMITH	Remarks on a property of Prime Numbers; on the Method of Quadratures; and a correction of the formula for the Area of a Curve when the arc is sub-divided into four parts Remarks on the discoveries of the late Judge Hargreave A property of the Periods of the Reciprocals of composite numbers Formula for the Multiplication of four Theta Functions*
18 June T. COTTERILL W. SPOTTISWOODE	Some properties of Cubic Curves A Problem in Probabilities connected with Parliamentary Elections
26 June T. COTTERILL A. DE MORGAN	On an Involution System of Circular Cubics, and description of the Curve by Points, when the Double Focus is on the Curve* Best straight line for approximating to the area of a curve

8 November	
J. J. SYLVESTER	Method of remembering Gauss's Formulae for Spherical Triangles
22 November	
W. K. CLIFFORD	On the General Theory of Anharmonics*
J. J. SYLVESTER	Development of the n th power of a Logarithm
R. TUCKER	Solution of the Problem, "Given a pair of conjugate diameters of an ellipse, to find any number of points on the Curve" ***
13 December	
G. C. DE MORGAN	On the development of a certain class of Functions
A. CAYLEY	Geometrical Drawings*

* = published in the Society's *Proceedings*.
 ** = published in the *Quarterly Journal of Mathematics*, Vol. 9, No. 33, p.25.
 *** = published in the *Mathematical Reprint of the Educational Times*, Vol. 7, p.28.

This change in the Society's status was entirely appropriate. The membership by this time stood at ninety-four, but now over half had no connection with University College at all. Nevertheless, the Society was still dominated by those who were London-based, or those, like Smith and Cayley, who were not far away. Even so, members from further afield, such as Robert Harley (Bradford) and James Maurice Wilson (Rugby), were to participate actively in the proceedings of the early years. Some contributed papers, even if they were prevented by distance from attending in person; for example, in 1867, Hirst communicated a paper, 'On the Inscription of a Polygon in a Ruled Quadric', on behalf of Richard Townsend of Trinity College, Dublin.

Thus, in only two years, the Society had more than trebled in size. While at its inception, the title 'London Mathematical Society' had seemed to somewhat magnify the scope of its membership, by November 1866 that name had, if anything, become something of an understatement. The Society may have originated at University College as something akin to an upper higher senior class of De Morgan's, but it had quickly outgrown the place of its birth to occupy a much wider arena. From little more than a college club, it had, in effect, become what it still remains - the national mathematical society.

Its second Annual General Meeting, on 8 November 1866, marked a further very definite break with University College; firstly by the fact that proceedings took place, for the first time, in the rooms of the Chemical Society at Burlington House, and secondly by the ending of De Morgan's period as President. A third, and perhaps

more symbolic, feature was the absence of the Professor on this particular evening. Although no explanation for his non-appearance is given, one does not have to look very far to realise that, at this precise point in time, he would have been occupied with far more pressing matters. At the very moment this meeting was taking place, a controversy which had been brewing in University College for some months was nearing a climax which would result not only in the end of De Morgan's teaching career, but the termination of his connection with the institution whose reputation he had done so much to advance.

5.3 Final Resignation

Throughout his long tenure of the professorship at University College, De Morgan's income, while adequate, had hardly been lavish. His lowest revenue in any single session amounted to £240 13s 4d of fees, after the usual deductions.¹⁵¹ This was in the year immediately following his return to the college in 1836, when the total number of students attending the mathematical classes had been a mere 54. Since then, however, the numbers had increased dramatically during the mid-1840s, reaching a peak of 123 during the 1848-49 session, a figure which represented an income of £565, his largest single earning in any academic year.¹⁵² So impressive were his class sizes during this time that on more than one occasion special reference was made to them in the college's annual reports, contrasting as they did with a general downturn in the overall student population.¹⁵³

Throughout the 1850s, his total student numbers remained healthy, fluctuating around one hundred, but the early sixties signalled a sudden decline in class sizes. This was largely due to the change in University of London regulations of 1858, after which it was not necessary for a student to have attended college lectures prior to entering for a degree. Consequently, by the 1863-64 session, De Morgan's class size had fallen to just 58.¹⁵⁴ A further effect of the new rules was a decrease in those attending the Patriot-funded evening classes for schoolmasters. From a maximum of

¹⁵¹ University of London, Session 1836-37, Statements of the Classes.

¹⁵² University College. Session 1848-49. Classes.

¹⁵³ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 26th February, 1845*, (London: Richard and John E. Taylor, 1845), 5; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 25th February, 1846*, (London: Richard and John E. Taylor, 1846), 5; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1849*, (London: Richard and John E. Taylor, 1849), 5, 7.

¹⁵⁴ University College. Session 1863-64. Classes.

67 students in 1853 and 1856, their numbers fell to just 13 in 1864,¹⁵⁵ when it was decided to discontinue them, thus depriving De Morgan of a further (albeit minor) source of income. This prompted one of his oldest colleagues to write the following letter to the initiator of the Patriot scheme:

Univ: Coll: Lond:
Nov.25. 1864

My Lord,

May I intrude upon your Lordship's privacy for a few lines. I write in reference to the employment of the Patriot fund. As the so-called Schoolmasters' classes died out of themselves, as soon as the University of London began to grant degrees without the condition of attendance at any College, it occurs to me that one of the best applications of the money for a time, would be the endowment *to some extent* of the chair of Mathematics *so long as* held by Prof. De Morgan. I find that the *net* receipts for his classes, so far as they go to his pocket, are about £250. Now no man devotes himself to the duties of his classes in the college with more zeal, more ability or more success, while his very name is of real advantage. Some of the Professors already receive from the college under one name or another an addition to their mere college fees. Such Professors are Mr. Potter, Dr. Sharpey, Mr. Malden. Could the money then be better bestowed than by adding a fixed sum, say £100, to Prof. De Morgan's fees. I have whispered the matter only to Mr. Malden and Dr. Sharpey, and no one *whatever* knows that I am now writing to your Lordship, who, without taking the trouble of replying to this notice, will best judge of the suggestion. I am your Lordship's very truly

T. Hewitt Key.¹⁵⁶

However, upon the cessation of the evening classes, the council, with Brougham's concurrence, ruled that "the Patriot Fund should be treated as part of the general Receipts of the College as long as there is an annual deficiency in the revenue of the College,"¹⁵⁷ so nothing came of Key's proposal. In any case, it is extremely unlikely that De Morgan would have accepted an endowment for his chair as this would have been tantamount to admitting that his lectures were not attracting enough students. Yet, by the mid-1860s, this was precisely the case. Indeed, as he later admitted, it was at this time that he began to seriously consider retirement, "on account of the general decadence of the College, which made the emoluments wholly out of

¹⁵⁵ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1865*, (London: Taylor and Francis, 1865), 5; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 25th February 1857*, (London: Taylor and Francis, 1857), 5-6.

¹⁵⁶ University College London Archives: Brougham Correspondence, No. 18,494, Thomas Hewitt Key to Lord Brougham, 25 Nov. 1864.

¹⁵⁷ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 28th February 1866*, (London: Taylor and Francis, 1866), 14.

reasonable proportion to the time the duties took".¹⁵⁸ Yet his final exit was destined not to be a quiet withdrawal, but was marked by another controversial resignation over a matter of principle. Furthermore, to De Morgan, the point at issue was even more fundamental than that which had prompted his departure in 1831.

5.3.1 The Peene bequest

It is perhaps ironic that the matter over which he was to resign in 1866 was not the first issue on which De Morgan had considered such action since his re-installation thirty years before. What is fitting is that they both concerned the same basic question: whether or not the college was truly impartial in matters of religion. Unequivocal secularity had been the college's fundamental maxim since its foundation forty years previously, a unique characteristic which had been its main attraction to De Morgan when he joined the college in 1828. Quite independently, however, another key feature since its creation had been long-term financial insecurity and a less than spectacular revenue. Hence the dependence on gifts and bequests such as the Patriot and Flaherty donations. To a man of De Morgan's firmly-held principles, the college's founding tenets would always come before monetary considerations. However, for the governing council, with its responsibilities to those with vested interests in the college, the situation was more involved. It was therefore perhaps inevitable that these two conflicting interests would eventually collide.

In a Will dated 9 March 1853, a Dr. William Gurden Peene, from Maidstone in Kent, bequeathed £1700 to the college, the interest of which was to be used annually to buy books for the library, mainly of foreign literature and science. However, the Will stipulated "that the selection of the books should be in the three Professors of Greek, Latin, and Mathematics, the same being members of the Church of England: otherwise that one or more should complete their number by choosing qualified persons from the other Professors, private teachers of the College, or *quondam alumni* resident in London. If none of the three named should be members of the Church of England, I beg the Council to appoint."¹⁵⁹ Predictably, this proviso caused some embarrassment to the council who had to balance their obligation to uphold the college's ethical principles with their need for financial contributions. Eventually, after lengthy discussions and having received contrasting opinions from many different sources, including De Morgan, they came to the following resolution:

¹⁵⁸ S. E. De Morgan, *op. cit.*, (5), 373.

¹⁵⁹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, 22nd February, 1854*, (London: Taylor and Francis, 1854), 8.

That the Council cannot but regret that the late Dr. Peene should have accompanied his valuable legacy by a direction with regard to the function of choosing the books which can by any construction be supposed to infringe that principle of religious equality to which the present Council and their predecessors have invariably adhered...

Considering, however, that the function in question is totally unconnected with the ordinary duties of the Professors, and might have been assigned by the testator to persons unconnected with the Institution, and that it is to be regarded as a trust under Dr. Peene's Will and not as a duty imposed by the authorities of the College, -

Considering also, that any Professor will have the power of declining the trust altogether, if he should for any reason think proper so to do, without being required to make any profession of his religious opinions, -

And lastly, considering that the value and utility of the proposed annual additions to the Library are not likely to be in any degree impaired by the terms of the bequest, - the Council have determined to accept Dr. Peene's Legacy, being of opinion that in so doing they do not violate that principle of religious equality on which the College was founded.¹⁶⁰

On being informed of this decision, De Morgan's first impulse was to resign his chair, viewing the council's awkward manoeuvre as "a shuffle"¹⁶¹ motivated by monetary rather than moral considerations. However, on reflection he decided against it, later justifying this resolution on the grounds that his concern for the welfare of the college outweighed personal considerations, that the classes were far from numerous,¹⁶² and that he preferred to remain until the college's general condition was more favourable. He was, however, not the only professor to object to the council's resolution. In fact, none of the three professors indicated in the Will agreed to participate in the scheme, forcing the council to appoint three former students instead. Nevertheless De Morgan believed that, by side-stepping the most significant clause in the college's constitution, the council had set a dangerous precedent. As his wife later reported, his comment at the time was: "'They have got in the thin end of the wedge; the next move will be a stronger one.' And so it proved."¹⁶³

5.3.2 The Martineau affair

Whereas De Morgan's resignation in 1831 had been due to the council's dismissal of a fellow professor, the matter which would lead to his final departure thirty-five years later centred around their appointment of a new one. In 1866, the Rev. John

¹⁶⁰ *ibid.*

¹⁶¹ S. E. De Morgan, *op. cit.*, (5), 189.

¹⁶² The total number of students in the college was still well below 1000, being only 769 during the session 1853-54.

¹⁶³ S. E. De Morgan, *op. cit.*, (5), 189.

Hoppus, who had held the chair of philosophy of the mind and logic since 1829, retired. The position was duly advertised and the deadline for candidates set for July. As had been the procedure since 1832,¹⁶⁴ the applications were referred to the professorial senate for report to the council. In this report, the senate recommended the appointment of the Rev. James Martineau (1805-1900) to the vacant position, concluding with the words:

All these considerations evidently lead to the conclusion that Mr. Martineau is the most eligible candidate. He appears to be at least equal to the other candidates in ability and learning, while he is superior to them both in reputation, and in experience and success as a teacher.¹⁶⁵

It was at this point that the internal politics of the institution came to the fore. From the college's formation, among the most dominant of its supporters had been the Unitarians who, at this point, occupied approximately one-third of the seats on the council. Martineau, in addition to his long-established reputation in the academic world, was also a prominent and highly controversial Unitarian minister.¹⁶⁶ Moreover, for some time he had been lecturing on mental, moral and religious philosophy at Manchester New College, then housed near to the college at University Hall in Gordon Square.¹⁶⁷ Consequently, those who disapproved of the growing Unitarian influence in college affairs were considerably disturbed by the prospect of his joining the professoriate in Gower Street.

The senate's report was received by the council on 4 August but, contrary to its usual policy of endorsement, the following resolution was moved:

That the Council consider it inconsistent with the complete religious neutrality proclaimed and adopted by University College, to appoint to the chair of the Philosophy of Mind and Logic a candidate eminent as Minister and Preacher of any one among the various sects dividing the religious world.¹⁶⁸

This motion was defeated, but so too was a proposal to accept the senate's recommendation, which was only decided by the chairman's casting vote.¹⁶⁹ As a

¹⁶⁴ See section 3.2.3.

¹⁶⁵ S. E. De Morgan, *op. cit.*, (5), 338.

¹⁶⁶ *D.N.B. 1st Supplement*, 3, 146-151.

¹⁶⁷ James Drummond and Charles Barnes Upton, *The Life and Letters of James Martineau*, (London: James Nisbet and Co., 1902), vol. 1, 409.

¹⁶⁸ Council Minutes, vol. X, 4 August 1866.

¹⁶⁹ Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 340.

result, the matter was postponed until their next meeting, scheduled for November. In the meantime, the vacancy was re-advertised, but no new candidates appeared. However, following the receipt of additional testimonials in favour of another of the candidates, George Croom Robertson (1842-1892), the senate was requested to make a second report. This concluded:

Upon the strength of this singularly strong testimony we have no hesitation in concluding that Mr. Croom Robertson is exceedingly well qualified to fill the vacant chair; and that of the candidates whose claims we have examined up to this point, he is the ablest, and, as far as we can judge, the most learned, and the most likely to rise to eminence, and to raise the reputation of the College. But there yet remains upon the list the name of Mr. James Martineau. As the Senate has already recommended the appointment of Mr. Martineau, and the Council has declined to appoint him, the Senate does not think it necessary to present a second report concerning him.¹⁷⁰

By now, news of the council's procrastination had reached the press and a vigorous public debate ensued in the daily papers throughout the autumn of 1866. For De Morgan, with his strong views on religious impartiality, the issue was of crucial importance. Indeed, when he heard "that the Council intended to reject Mr. Martineau for reasons connected with religious belief, he openly declared that should the College make such a departure from the principle on which it was founded, he should feel that his connection with it was at an end".¹⁷¹ This rejection duly came at the council's next meeting on 3 November, after which De Morgan's response was inevitable. One week later, on 10 November 1866, in a lengthy and thoughtfully-composed letter, he tendered his resignation.¹⁷²

The principal justification given for his action was that the council had refused to appoint a professor on the basis of his religious views and was therefore as guilty of imposing doctrinal restrictions as Oxford or Cambridge. But there was also a more personal aspect underlying this decision. While he had always refused to publicly ally himself with any religious denomination, it was his wife's belief that "he had most respect for the Unitarians".¹⁷³ This is borne out by his resignation letter, in which he claims to be as worthy of exclusion as Martineau, since for over thirty years, he had held the same religious views. However, he had abstained from expressing such opinions, not from fear of expulsion, but from the intense conviction that such beliefs were nobody's concern but his own.

¹⁷⁰ S. E. De Morgan, *op. cit.*, (5), 338.

¹⁷¹ *ibid*, 339.

¹⁷² This letter is given in full in Appendix C.

¹⁷³ S. E. De Morgan, *op. cit.*, (5), 86.

As with any study of De Morgan, his lifelong commitment to strongly-held principles cannot be overstressed. Foremost among these were his uncompromising nonconformist tendencies and the emphasis he placed on his position as a "Christian unattached". The outcome was an unalterable belief that religion was entirely irrelevant in determining ability in matters concerning public life. This formed the guiding principle of his career, having previously resulted in his rejection of an academic career at Cambridge and his employment by the first secular college in the country. It is therefore deeply ironic that it also occasioned his resignation from this very institution when he felt its non-sectarian principles had been compromised.

5.3.3 The Aftermath

Martineau's election was prevented by a combination of those on the council who objected to his philosophy as idealistic, those who believed his religion was too unorthodox and those who objected to any increase in Unitarian representation within the college.¹⁷⁴ Yet, ironically, the whole situation could have been avoided had it not been for one particular individual. Henry Crabb Robinson was a council member of thirty years standing who was of the same opinion as De Morgan on the question of Martineau's appointment. However, he was prevented from attending the fateful meeting on 4 August by his manservant who, according to him, wanted to go to Brighton. Consequently, it was not until after they had left London on 1 August that Robinson was shown the notice of the meeting,¹⁷⁵ by which time it was too late to attend. Had he been present, his vote would have ensured Martineau's election and De Morgan need never have resigned.

The controversy simmered on in the press for the next few months, with various publications taking alternate positions, although according to Hirst's diary: "All the newspapers except the *Examiner* and *Nonconformist* are against the [council's] decision."¹⁷⁶ Notwithstanding this public criticism, the council elected George Croom Robertson to the disputed professorship on 8 December.¹⁷⁷ This appointment was ratified at a meeting of the college proprietors on 2 February 1867, when "their vote of censure on the Council apropos of the rejection of Martineau was lost by a minority of 37 to 42".¹⁷⁸ A final attempt to reverse the decision was defeated at the

¹⁷⁴ *ibid*, 341-342, 350-351, 369, 374; Drummond and Upton, *op. cit.*, (167), 409, 411.

¹⁷⁵ Sadler, *op. cit.*, (12), 515.

¹⁷⁶ Brock and MacLeod, *op. cit.*, (119), 1794.

¹⁷⁷ Council Minutes, vol. X, 8 December 1866.

¹⁷⁸ Brock and MacLeod, *op. cit.*, (119), 1798.

Annual General Meeting three weeks later.¹⁷⁹ In the meantime, steps were taken to appoint a successor to De Morgan in the chair of mathematics.¹⁸⁰

Although De Morgan had resigned in November, he continued to discharge his duties at college for the remainder of the 1866-67 session. This must have been a particularly uncomfortable experience, to say the least. Most unpleasant, however, was the fact that not one of his colleagues supported his actions. Whereas in 1831, his resignation had been followed by those of several other professors with similar principles, this time he stood completely alone. Indeed, from his wife's account of his final year at the college, there seems to have been an embarrassing silence among the professoriate on the matter of his imminent departure: "My husband told me that during the session in which he worked after his resignation was sent in he met his colleagues as before in the Professors' room. Not one of them ever spoke on the subject of his retirement, and he left the place without one word of acknowledgement for all he had done for it."¹⁸¹

He was especially saddened by those, such as Key and Malden, who had been his colleagues virtually from the beginning, and who were as familiar as he was with the college's founding principles. However, he assumed that their silence was motivated by a desire to avoid causing further offence. Although more inclined to tolerate the attitude of the more recently appointed professors, he informed a friend that "two of the younger ones, indeed, undertook to instruct me that I was wrong about the principle of the College, which I had studied before they were born".¹⁸² But this insensitivity was not universal among the college's younger generation. As the session, and De Morgan's career, neared its conclusion, a group of his former students led by Jacob Waley, who himself had recently relinquished his professorship at University College, made the following appeal to their former professor:

May 7, 1867

Dear Sir,

Many of your old pupils, at whose request we address you, desire, upon your resignation of a chair which for upwards of thirty years you have filled with so much distinction, to give some appropriate expression to the high estimation in which they hold you.

Our admiration for your philosophical views of education, your skill in the art of instruction, and your scientific attainments, as

¹⁷⁹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 27th February 1867*, (London: Taylor and Francis, 1867), 6; Drummond and Upton, *op. cit.*, (167), 412.

¹⁸⁰ *The Times*, 25 Jan. 1867, 7a; *ibid*, 12.

¹⁸¹ S. E. De Morgan, *op. cit.*, (5), 358.

¹⁸² *ibid*, 375.

well as our cordial regard and esteem for you as our old teacher and friend, render us desirous of recording these feelings in some substantial shape.

We understand, however, that you feel you cannot consistently accept any testimonial of intrinsic value. But we hope that you may be persuaded to gratify your pupils by sitting for a picture or bust to be placed in the library of our old College. We remain, sir,

Yours faithfully,

Jacob Waley

W. A. Case

J. G. Greenwood

G. Jessel

Richard Holt Hutton

Walter Bagehot

H. M. Bompas

R. B. Clifton

J. M. Solomon

H. Cozens Hardy

Theodore Waterhouse¹⁸³

Such a sincere and courteous request would clearly have been very moving to De Morgan, and certainly generated very conflicting emotions in him: on the one hand, immense gratification at such warmth of feeling on the part of those he had once taught; yet on the other, an intense aversion to any reference to his association with the institution where all this teaching had taken place. He was clearly uncertain as to whether he should view his life's work as a success or a failure, since it was inextricably linked to a body to which he now viewed with revulsion. The resulting mental confusion into which his resignation had thrown him is particularly evident in his reply:

My Dear Waley,

I acknowledge your kind letter of the 7th with the cordial and gratifying enclosure, signed by eleven old pupils, whose dates represent the time which has elapsed since I rejoined the College in 1836.

The inclosure is in itself a testimonial. It has all the meaning and all the value. And to those who hold that the mind of the teacher counts for something in the making of the pupil, the string of names appended to it will be no mean presumption that I have in some degree a claim to the terms in which I am described.

I am asked to sit for a bust or picture, to be placed in what is described as "our old College." This location is impossible; our old College no longer exists. It was annihilated in November last.

The old College to which I was so many years attached by office, by principle, and by liking, had its being, lived, and moved in the refusal of *all religious disqualifications*. Life and soul are now extinct.

I will avoid detail. I may be writing to some who think that the recent transaction is a reparable dilapidation, or even to some who

¹⁸³ *ibid*, 359.

approve of it. To me the College is like a Rupert's drop with a little bit pinched of the small end; that is, a heap of dust.

I can never forget that I have been usefully employed, though I now wish my life had been passed in any other institution. I have worked under the conviction that I was advancing a noble cause, until every letter in the sentence "Augustus De Morgan, Professor of Mathematics in University College, London," stands for 234 hours of actual lecturing, independent of all study and preparation; and all this under a banner which is now shown to have been either shamfully raised or shamefully deserted.

So much is necessary that my old pupils may understand my mind, and the repugnance I feel towards any proceeding which must record my connection with University College. I am happy to say that the circumstances have not created any personal bitterness of feeling; individuals are to me what they were before. But if force of will can succeed, the institution is to pass away from before my mind, and to become as if it had never existed.

You will see that I am altogether averse to lending aid or countenance to any scheme which will tend to remind others that I was a teacher in the College which did homage to the evil it was created to oppose.

But I am even more sensible to my old pupils' remembrance than I should have been if I could have accepted the result of their most acceptable good opinion. Such remembrance would have been, in any case, a treasure. It has now the additional value of a treasure saved out of the fire.

You will, of course, communicate my answer, and with my warmest thanks and most heartfelt regards,

I am, my dear Waley,

Yours sincerely,

A. De Morgan.¹⁸⁴

At the end of the session, De Morgan made one final visit to the college to collect the notebooks containing his mathematical tracts from the library. After this, we are told, he never entered the building again. After more than thirty years, De Morgan's association with University College was finally at an end.

The months of controversy and turmoil surrounding his resignation had clearly been immensely stressful for the now ailing professor. Yet, within months of his retirement, a further affliction befell both him and his family. His son George, in many ways the closest of his children to him, not least because of his mathematical skills, had been in a delicate state of health for some time. His death in October 1867 at the age of just 26 devastated his father and robbed the world of a mathematician

¹⁸⁴ *ibid*, 360-361.

of very great promise. Yet, in a letter to John Herschel, De Morgan was philosophical about his loss:

I bear it well, and so does my wife. Many condoling friends have found out that the great and special force of the blow is that he was the son who was to follow in my footsteps, and had made some beginning. To which I assent; but, truth to speak, I did not remember this until I was told, nor did it produce any effect. I am peculiar, I suppose. I remember with satisfaction that he and a young fellow-student were the projectors of the Mathematical Society, which seems to have taken firm root; but this is only the general love of memorial which belongs to our nature. Any other instance would do as well. A strong and practical conviction of a better and higher existence does much better for every purpose, and reduces the whole thing to emigration to a country from which there is no way back, and no mail packets, with a certainty of following at a time to be arranged in a better way than I could do it.¹⁸⁵

No doubt motivated by a wish to prolong the memory of his son, in addition to a genuine interest in its welfare, De Morgan's involvement with the London Mathematical Society continued well into his retirement, including further contributions to its meetings.¹⁸⁶ However, from this point, his attendance became increasingly irregular as his previously robust state of health began to decline. He remained on the Society's committee, serving as Vice-President from 1866 to 1868 and again from 1869 to 1870, but in 1868 he suffered a stroke which left him dramatically weakened and from which he never fully recovered. His physical deterioration was further exacerbated by the onset of a kidney disorder which "during more than two years of distressing illness reduced him to a shadow of his former self".¹⁸⁷

Yet, although much weakened by his condition, De Morgan continued to write, producing further articles and mathematical papers. His actuarial work also continued, his final such undertaking being a large calculation for the Alliance Assurance Company. He also added further material to his manuscript book of his family history, a by-product of which was a biography of his great-grandfather,¹⁸⁸ one of his final publications during his lifetime. He was still able to entertain guests, writing to Hirst in 1868 that "My wife finds tea for any who choose to drop in on a

¹⁸⁵ Royal Society Herschel Archives, MS.HS 6.400, De Morgan to Sir John Herschel, 18 Oct. 1867.

¹⁸⁶ Augustus De Morgan, On the conic octagram, *Proceedings of the London Mathematical Society*, (1), 2 (1866-69), 26-29; On general numerical solutions, *ibid*, 84-85.

¹⁸⁷ Ranyard, *op. cit.*, (70), 118.

¹⁸⁸ Augustus De Morgan, Some Account of James Dodson F.R.S., *Journal of the Institute of Actuaries and Assurance Magazine*, 14, Part V, No.LXXIII, (October, 1868), 341-364.

Thursday Evening at 8 P.M. without ceremony".¹⁸⁹ Indeed, he was receiving visitors until 1870, two special guests of that year being the young Charles Peirce and the Russian mathematician Pafnuty Lvovich Chebyshev (1821-1894).¹⁹⁰ However, the premature death of another child, Helen Christiana, in August 1870 prompted the final decline in his health. He died in the early afternoon of Saturday 18 March 1871,¹⁹¹ and was buried five days later at Kensal Green cemetery in north-west London.¹⁹²

In the months following De Morgan's death, numerous memorials and obituaries appeared from various sources, each paying tribute to his many and varied achievements as a mathematician, logician, and scientific writer. One of the comments most frequently made regarded the sheer breadth and volume of his published work. The notice in *The Athenæum*, to which he had been a regular contributor since 1840, asserted that if all his articles for periodicals and encyclopaedias were collected together, there would be found "such a mass of literary achievement as seldom comes from the pen of a man whose sole business it is to write for journals."¹⁹³ However, as the articles written by former students maintained, it was his work as a teacher which deserved particular emphasis, not least because it provided the best insight into his personal character.

Indeed, as Arthur Cowper Ranyard opined in his obituary: "A very inadequate notion of Professor De Morgan will be formed by those who look only at his works. From them, indeed, it will be seen that he was a reader who relished every kind of intellectual food, and a thinker whose subtlety was only surpassed by his originality. They abound also with proof that he overflowed with humour; but his familiar associates alone can render justice to the versatility of his powers and the sweetness of his disposition.... He was the kindest, as well as the most learned, of men - benignant to every one who approached him, never forgetting the claims which weakness has on strength."¹⁹⁴

Yet De Morgan's death did not merely inspire the composition of numerous laudatory obituaries by erstwhile pupils. So universal was their affection for their old professor that, within weeks of his death, a committee was formed by his former students for the purpose of creating some permanent memorial to his work. Its three

¹⁸⁹ LMS Papers, De Morgan to Thomas Archer Hirst, 6 Feb. 1868.

¹⁹⁰ Brock and MacLeod, *op. cit.*, (119), 1885.

¹⁹¹ *The Times*, 20 March 1871, 1a; 21 March 1871, 5c.

¹⁹² Brock and MacLeod, *op. cit.*, (119), 1896.

¹⁹³ *The Athenæum*, No. 2265, 25 March 1871, 370.

¹⁹⁴ Ranyard, *op. cit.*, (70), 118.

principal suggestions were the commissioning of a bust, the purchase and preservation of his extensive mathematical library, and the inauguration of a De Morgan medal under the auspices of the London Mathematical Society.¹⁹⁵ Yet, commenting on the proposed tributes, *The Spectator* no doubt spoke for many former students when it declared that "no testimonial which can be raised to Professor De Morgan will adequately express his many pupils' deep sense of intellectual and moral obligation".¹⁹⁶

Yet it was not just those who had come into direct contact with De Morgan who were moved to write in his praise. Indeed, two of the most lavish compliments came several decades after his death from mathematicians who, while both former students of University College, had never experienced his teaching or even made his acquaintance. The first, M. J. M. Hill (1856-1929), only ten years old when De Morgan left the college, became its professor of mathematics nearly twenty years later. From a combination of a close study of De Morgan's work, and conversations with former colleagues and students, he developed such an admiration for his predecessor, that, while he had never known him, he was able to opine that "amongst the great men who have lectured within the walls of the College he was probably by reason of his scholarship, by the profundity of his work, and by his personal character, one of the greatest, if not the greatest of them all."¹⁹⁷

But perhaps the most perceptive and candid judgement came from Walter William Rouse Ball (1850-1925), another student who attended the mathematical classes at University College after De Morgan's resignation. He had entered the college in October 1867, in other words, in the session immediately following De Morgan's departure. Like Hill, he too exhibited a sincere and striking reverence for the Professor, although he had never known him. Yet, in an article written nearly half a century after his death, he was able to encapsulate De Morgan's personality and character in a paragraph which, as well as going some way to explaining why he commanded such widespread respect and affection during his lifetime, serves as a fitting epitaph for one of the most eccentric yet brilliant figures in the history of mathematical education.

¹⁹⁵ All three objectives were achieved: the bust, executed by Thomas Woolner, is now housed in the University of London Library, as are the mathematical books; and the De Morgan medal of the Mathematical Society, awarded triennially from 1884, soon became one of the highest honours a mathematician could receive in Britain.

¹⁹⁶ *The Spectator*, 13 May 1871, 563.

¹⁹⁷ M. J. M. Hill, "Some Account of the Holders of the Chair of Pure Mathematics from 1828 to the Present Time", MS (1924), University College Archives, Materials for the history of UCL, Mem. 2A/19, f.4.

That De Morgan was obstinate and somewhat eccentric I readily admit, and I do not consider he was a genius, but he leaves on my mind the impression of a lovable man, with intense convictions, of marked originality, having many interests, and possessing exceptional powers of exposition. In those cases where his actions were criticized it would seem that the explanation is to be found in his determination always to take the highest standard of conduct without regard to consequences; he hated suggestions of compromise, expediency, or opportunism. Such men are rare, and we do well to honour them.¹⁹⁸

¹⁹⁸ Walter William Rouse Ball, Augustus De Morgan, *The Mathematical Gazette*, **8** (1915-16), 42-45, p.45.

Chapter 6

Successive Successors - University College after De Morgan, 1867-1900

6.1 Pure Mathematics up to 1880

De Morgan's retirement in 1867 signalled the end of an era for University College in more than one respect, not least because he was one of the last remaining professors to have been associated with it from the very beginning. His departure marked the severing of a connection which had existed – with the exception of the years 1831-36 – since the opening of the college nearly forty years previously. Indeed, referring back to the list of founding professors (in section 2.2.2), we see that, at the time of his resignation, De Morgan was one of only three original members of staff who still remained in the service of the college. Now only Thomas Hewitt Key, as professor of comparative grammar and headmaster of the school, and Robert E. Grant, the professor of comparative anatomy, were left. They too would be gone within a few years.¹

But it was not just the personnel that was changing. De Morgan's departure occurred during a period made conspicuous by numerous reforms within University College which signalled a very definite break with its early years. One of the most symbolic was the inauguration of a new constitution in 1869.² This finally abolished the system of proprietors and shares upon which the college had been founded – and which had, in fact, been obsolete for many years, as illustrated by its impotence over Martineau's rejection. This severing of links with the past was accompanied by progressive steps towards future development. One key feature of the new constitution was that it enabled the college to provide instruction for both sexes, as well as enlarging the scope of subjects taught. For example, in 1870, to fully promote its teaching in the sciences as well as to meet the growing demand for such instruction, the college established a separate Faculty of Science.³ Mathematics was naturally included in this

¹ Both men died in office: Grant in 1874, Key the following year.

² *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 24th February 1869*, (London: Taylor and Francis, 1869), 4, 15, 16-18; *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 23rd February 1870*, (London: Taylor and Francis, 1870), 8-9.

³ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1871*, (London: Taylor and Francis, 1871), 15.

new faculty, although it also retained representation within the Faculty of Arts.

A further opportunity to reorganise mathematical tuition at the college was afforded by De Morgan's departure. As with the retirement of Richard Potter two years previously, this occasion was fully exploited, with not only the designations but also the responsibilities of the mathematical chairs being substantially altered. Modifications were to continue during the subsequent three decades, chiefly prompted by changes in the occupants of these chairs, which occurred far more frequently during this period than in the previous thirty years (see Table 1). Indeed, it is interesting to note that in the thirty-three years following De Morgan's withdrawal, no fewer than four different people would occupy the chair which he had held for the same duration. It is not surprising, therefore, that many changes would be introduced into the mathematical syllabus, affecting not just what was taught at the college, but also the manner of its instruction. This chapter, therefore, will be survey of these alterations, as initiated by De Morgan's successors at University College up to the turn of the century, beginning with tuition in pure mathematics.

Table 1

University College Professors of Mathematics 1865-1900

	<u>MATHEMATICS</u>	<u>MATHEMATICAL PHYSICS</u>
1865	Augustus De Morgan	Thomas Archer Hirst
	<u>PURE & APPLIED MATHEMATICS</u>	
1867	Thomas Archer Hirst	
	<u>PURE MATHEMATICS</u>	<u>APPLIED MATHEMATICS</u>
1868	Thomas Archer Hirst	Benjamin T. Moore
1870	Olaus Henrici	William Kingdon Clifford
1871		
1880	Richard Charles Rowe	Olaus Henrici
1884	M.J.M. Hill	Karl Pearson

6.1.1 Thomas Archer Hirst

By 1867, University College was firmly established as the centre for advanced mathematical tuition in London. This had been due not only to De Morgan's teaching, but also to what was described by one of his colleagues as "that European reputation which he possesses as one of the great scientific men of the age".⁴ With such a high position to maintain, the college would therefore have been anxious to secure the services not only of a first-class mathematician, but also someone who was known to be an able and successful teacher. Thus, while applications for the professorship were received until 4 April 1867,⁵ it is conceivable that the council had a successor in mind when they advertised the post, already having an ideal replacement in the form of their professor of mathematical physics.⁶ This was none other than Thomas Archer Hirst, who received notification on 5 May "that the Council had elected me unconditionally and most unanimously to the chair of Mathematics at University College".⁷

His appointment occasioned a further readjustment in the college's teaching of mathematics and physics. It will be remembered that, upon Hirst's election to the chair of mathematical physics in 1865, George Carey Foster had been chosen as the professor of experimental physics. In 1867, Foster's chair was renamed simply physics, while Hirst combined his new duties in pure mathematics with those of mathematical physics under the newly created title of Professor of Pure and Applied Mathematics.⁸ His promotion was also the occasion of another innovation in the teaching of mathematics at University College. Whereas De Morgan had taught all classes single-handedly for over thirty years, Hirst requested, and was permitted, to employ an assistant to take his problem classes for him, thus easing his workload. (This assistant was Olaus Henrici, who will be discussed shortly.)

This arrangement lasted for just one year. In 1868, finding the increased duties an impediment to original research as well as his health, Hirst resigned the applied chair in order to concentrate on pure mathematics alone. This coincided with a report by the senate in which the establishment of a new professorship of applied mechanics was recommended. This proposal was accepted by the council and, as a result of Hirst's reallocation of his duties, a new chair of applied mathematics and mechanics

⁴ *University College, London. Calendar. Session 1867-68*, (London: James Walton, 1867), 50.

⁵ *The Times*, 25 Jan. 1867, 7a.

⁶ This may perhaps explain the absence of a record of applicants.

⁷ William H. Brock and Roy M. MacLeod (eds.), *Natural Knowledge in Social Context: The Journal of Thomas Archer Hirst, F.R.S.*, (London: Mansell, 1980), 1803.

⁸ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 26th February 1868*, (London: Taylor and Francis, 1868), 10.

(effectively equivalent to the old chair of mathematical physics) was created.⁹ This new department was intended to provide courses in mechanics, hydrostatics and astronomy for candidates for the B.A. and B.Sc. examinations, as well as instruction in applied mechanics for engineering students¹⁰ and was soon to have some very distinguished occupants.

Although Hirst's tenure as professor was fairly brief, he did manage to institute a few significant changes to the way mathematics was taught at the college. The first was a re-structuring of his students' classes, where he appears to have amalgamated De Morgan's lower and higher junior classes to form one combined group, resulting in just three mathematical divisions: the junior, senior and higher senior. This did not affect the overall course structure, however; the recommended duration was still two years and, as far as content was concerned, officially at least, Hirst's new mathematical course does not seem to have departed far from that of his predecessor:

JUNIOR CLASS: The Elements of Plane Geometry; the Principles and Operations of Arithmetic and Algebra, including the Theory and use of Logarithms; Plane Trigonometry; Solid Geometry, including the elementary properties of the Cylinder, Cone and Sphere; Spherical Trigonometry.

SENIOR CLASS: Higher Algebra, including the Theory of Equations and the elements of the Theory of Determinants; the Higher Pure Geometry, including the Theories of Anharmonic Ratios, Homography and Involution, and their applications to Conic Sections, &c; Coordinate Geometry of two and three dimensions; the elements of the calculus of Probability.

HIGHER SENIOR CLASS: Differential and Integral Calculus, including the integration of differential equations and geometrical applications. The Calculus of Finite Differences, of Variations, and of Probability.¹¹

One of the few additions to the general course was his introduction of the theory of determinants into the senior class, although one of his predecessor's mathematical tracts would imply that De Morgan's higher seniors had previously been given a basic grounding in the subject, albeit briefly.¹² However, it was what Hirst omitted from the

⁹ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 24th February 1869*, (London: Taylor and Francis, 1869), 11.

¹⁰ William P. Ker (ed.), *Notes and Materials for the History of University College, London. Faculties of Arts and Science*, (London: H. K. Lewis, 1898), 66-67.

¹¹ *University College, London. Calendar. Session 1869-70*, (London: James Walton, 1869), 31.

¹² University of London Library, MS. 775/217.

course that was far more consequential. As has been well chronicled elsewhere,¹³ the nineteenth century was witness to an intense debate among mathematicians about the value of Euclid as a didactical tool. We have seen, in section 3.1.3, that De Morgan, notwithstanding his criticisms of its structure and complexity, was solidly in favour of its retention, believing its primary virtue to be the logical discipline it instilled in the mind.

Hirst, however, sided firmly with those who urged for its abandonment, concurring fully with many prominent mathematicians of the day that, in the words of Sylvester, it should be "honourably shelved or buried 'deeper than did ever plummet sound' ".¹⁴ This conviction had arisen from his years as a surveyor during the 1840s, as well as his experience of teaching geometry in University College School during the early 1860s. He was to pursue his belief with considerable effect, becoming in 1871 the first president of the body established to reform the teaching of geometry in schools, the Association for the Improvement of Geometrical Teaching (or A.I.G.T.).¹⁵ On assuming the chair of pure mathematics, one of the earliest results of this philosophy was his removal of Euclid from all geometrical instruction. Henceforth at the college, Euclidean geometry would be taught without reference to Euclid's *Elements*.

Probably because his tenure of the professorship was so brief, especially in comparison to that of De Morgan, there is a considerable dearth of student-authored accounts of Hirst's teaching. Nevertheless, judging from available information, he appears to have been a successful and respected teacher:

His appearance was striking. He was tall, held himself erect, with an almost military air. He had a long black beard and a great, bald, dome-like forehead. He was a man with whom it was impossible to imagine the most audacious student venturing to take a liberty. There was something about him that invested his unlovely subject with dignity, if not with interest. Less, perhaps, than any of the other professors, did he seem to think of examinations. To him, I believe, incredible as it

¹³ For example: William H. Brock, *Geometry and the Universities: Euclid and His Modern Rivals 1860-1901*, *History of Education*, **4** (1975), 21-35;

Florian Cajori, *Attempts Made during the Eighteenth and Nineteenth Centuries to Reform the Teaching of Geometry*, *American Mathematical Monthly*, **17** (1910), 181-201;

Michael H. Price, *Mathematics for the Multitude? A History of the Mathematical Association*, (Leicester: The Mathematical Association, 1994), 19-33, 53-63;

Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England*, (Boston: Academic Press, 1988), 161-198.

¹⁴ James Joseph Sylvester, Presidential Address: Mathematics and Physics Section, *Report of the Thirty-ninth Meeting of the B.A.A.S. held at Exeter in August, 1869*, (London: John Murray, 1870), 1-9; reprinted as "A plea for the mathematician," *Nature*, **1** (1869-70), 237-9, 261-3, p.261.

¹⁵ J. Helen Gardner and Robin J. Wilson, Thomas Archer Hirst - Mathematician Xtravagant VI. Years of Decline, *American Mathematical Monthly*, **100** (1993), 907-915, p.910.

sounds, mathematics must have been a solemn, high pursuit; a passion, if not a religion. Yet with all his aloofness of manner he could be very simple, very patient, and extremely kind. Certainly to one of his most hopeless pupils he showed himself all three.¹⁶

Despite having reduced his workload by resigning the applied chair and employing an assistant to teach his exercise classes, Hirst still found that his administrative and professorial duties left him inadequate time in which to pursue his mathematical research. In his diary for February 1869, he records his frustration: "At home writing paper on Degenerate Conics. This paper perplexes me sorely. I begin to fear that it will never be satisfactorily written until I can work at it uninterruptedly. My daily duties so absorb my thoughts that I can only in leisure hours succeed in turning them to this new work, and no sooner are they turned and effective work rendered possible than the said duties turn them away again."¹⁷ Yet, despite the limitations imposed on his geometrical investigations, Hirst was pragmatic about his situation: "My first duty is to earn my bread by teaching; if original research is not compatible with the performance of this duty then I must sacrifice originality however dear to me it may be, or however much my science might be advanced thereby. If the mathematical world prefer my teaching to my researches what right have I to complain? Can I even say that its choice is a bad one? I doubt it."¹⁸

This resolve did not last. Precisely one year later, he decided to resign his professorship and apply for a non-academic post which would be less demanding on his time:

The fact that I cannot at present do any original work; that it is only by devoting myself wholly to lecturing that I can keep up my number of students at the College and thus secure my bread; that as my strength fails my prospects will necessarily be worse at University College; these facts I say decided me at length to apply for an appointment of an inferior order, perhaps, but of a less arduous and more remunerative character. Moreover, if I succeed I shall come in contact with good and influential men and myself be able to influence to some extent the character of Education in England.¹⁹

The post for which Hirst had applied was the newly-created position of Assistant Registrar of the University of London. The job, whose duties included registration of candidates for examination, supervision of certificates, and keeping fees and accounts,

¹⁶ B. P. Neuman, Gower Street in the 'Seventies, *The Nineteenth Century and After*, **87** (1920), 293.

¹⁷ Gardner and Wilson, *op. cit.*, (15), 909.

¹⁸ *ibid.*

¹⁹ Brock and MacLeod, *op. cit.*, (7), 1859.

was intended for "a gentleman of high education and good manners".²⁰ The salary was a substantial £500 per annum. On receiving the appointment, he tendered his resignation at University College.²¹ In accepting it, the council recorded "their great regret at losing your services in the important Chair of Mathematics, in which you have displayed not only eminent abilities as a Mathematician, but great skill as a Teacher and conscientious devotion to the duties of your office. These qualities have had a marked effect in increasing the number of students in the Classes of Mathematics during your tenure of the Professorship, and have thus contributed in no small degree to the welfare and reputation of the College."²²

6.1.2 Olaus Henrici

For the remainder of the session, Hirst's duties were performed by his assistant, himself an experienced and very able teacher. This was Olaus Magnus Friedrich Erdmann Henrici (1840-1918), an intriguing and capable mathematician whose name, like that of Hirst, is somewhat forgotten today. Born in Denmark, Henrici had studied mathematics in Germany from the age of nineteen, first under Rudolf Clebsch (1833-1872) at the Karlsruhe Polytechnicum and then at Heidelberg with Ludwig Otto Hesse (1811-1874). Obtaining his doctorate, he moved to Berlin where he studied under Karl Weierstrass (1815-1897) and Leopold Kronecker (1823-1891). He then became a *privatdozent* at Kiel University but, being unable to support himself, came to London in 1865.

Struggling to earn a living, he provided for himself by teaching elementary mathematics to school boys, an experience which was to prove invaluable in his subsequent career, since he not only learnt how "to probe the working of the minds of his pupils",²³ but also "acquired the power of expressing himself with great clearness both in teaching and in writing".²⁴ Obtaining an introduction from Hesse to Sylvester, he soon became acquainted with many of the foremost British mathematicians of the day, including Arthur Cayley, William Kingdon Clifford and Thomas Archer Hirst. In 1867 he became Hirst's assistant at University College and, during the session 1869-

²⁰ *ibid*, note 275.

²¹ UCL College Correspondence, Thomas Archer Hirst to Council, 7 April 1870.

²² Letter from John Robson to Thomas Archer Hirst, 11 April 1870, quoted in Brock and MacLeod, *op. cit.*, (7), 1870.

²³ M. J. M. Hill, Obituary notice of Olaus Henrici, *Proceedings of the London Mathematical Society*, (2), 17 (1918), xlii-xlix, p.xlix.

²⁴ M. J. M. Hill, "Some Account of the Holders of the Chair of Pure Mathematics from 1828 to the Present Time", MS (1924), University College Archives, Materials for the history of UCL, Mem. 2A/19, f.5.

70, also held the mathematical professorship at Bedford College for women²⁵ (see Chapter 7).

In April 1870, shortly after Hirst's resignation, Henrici took over his duties, delivering the remainder of his lectures for him as a temporary substitute. A few weeks later he was appointed the new professor of pure mathematics. Immediately on hearing of his election, he wrote a letter to his former employer, the content of which leaves us in no doubt as to whose influence he believed his appointment was due:

142 Hampstead Road N.W.
June 7th 1870

Dear Prof. Hirst

I was not a little surprised when I got your letter this morning which brought me the first news of my appointment. I thank you most sincerely for your congratulations but much more for your exertions on my behalf. Without your assistance I should never have obtained the Professorship.

I shall do my best to fill up the place; although I am aware of the difficulties which the successor of so powerfull [sic] a teacher as my predecessor necessarily must experience.

Let me repeat my thanks and assure you that

I remain for ever
yours thankfully
O Henrici.²⁶

For the first five or six years of his tenure, Henrici seems to have administered the mathematical tuition in much the same manner as his predecessor: the course outlines remained unchanged, the classes were categorised identically, and he also employed an assistant to take his exercise classes.²⁷ Whether any changes were unofficially inserted is difficult to tell, since they are not recorded in any prospectus of this time. However, in 1876, a major innovation was introduced. In that year, an announcement appeared in the *University College Calendar* advertising a new course entitled Modern Geometry and Graphical Statics.

"In this Course," said the prospectus, "Geometry will be treated by modern as distinguished from Euclidean methods, and previous knowledge of Euclidean Geometry, though advantageous, will not be

²⁵ Margaret J. Tuke, *A History of Bedford College for Women 1849-1937*, (London: Oxford University Press, 1939), 344.

²⁶ Letter from Olaus Henrici to Thomas Archer Hirst, 7 June 1870, quoted in Brock and MacLeod, *op. cit.*, (7), 1877.

²⁷ This was Percy J. Harding, who had been a pupil at the school (1859-62) and a student at the college (1862-65) before entering Sidney College, Cambridge, in October 1865. He obtained his B.A. degree in 1869, becoming Henrici's assistant the following year, as well as succeeding him as professor of mathematics at Bedford Ladies' College.

absolutely necessary in order to follow the Lectures.... One of the great advantages of the purely geometrical methods is that all operations are performed by constructions, mostly in three dimensions. Thus the Student learns to realize figures in space; whilst in Coordinate Geometry the geometrical meaning of the algebraical operations is too easily lost sight of."²⁸

It will be recalled from Chapter 4 that, ten years previously, Hirst had tried in vain to give a series of evening lectures under the title of modern geometry but had met with opposition from De Morgan and apathy from the students. Indeed, although De Morgan's regular course had covered the theory of perspective and projective geometrical methods, the material he taught had only included the work of Pascal, Monge, Poncelet and Brianchon (i.e. up to the early part of the nineteenth century). Henrici had now taken the bold step of including results from the likes of Chasles, Steiner and Plücker into his undergraduate course. This marked the introduction of far more recent continental projective geometry into the pure mathematics syllabus, which now included the following additional subjects:

Straight Lines and Planes in Space; Pencils of Lines and Planes; Ranges of Points; Projections and Projective Figures; Harmonic Pencils and Ranges; Principle of Duality; Measurement and Ratio; Equal and Similar Figures; Cross Ratios; Projective Ranges and Pencils; Theory of Conics, Cones, and Ruled Quadric Surfaces.²⁹

To help his students with this new geometry, Henrici ran classes for geometrical drawing and the construction of models. He also published a small book, *Congruent Figures* (1879), "with the object of familiarising students from the very first with those modern methods, of which the method of projection and the principle of duality are the most fundamental".³⁰ It would appear that he intended this work to be supplemented by another, since in his preface he says that "the advantages of the method adopted will, however, be fully appreciated only in their continuation in the second volume, which will treat of areas in connection with what Möbius calls 'equal figures' and of similar figures".³¹ This second volume never appeared.

The second half of his new course, graphical statics, was another major innovation, being the first such course in the country. This also introduced recent geometrical methods into the mathematical syllabus, thus making Henrici's course far more

²⁸ *University College, London. Calendar. Session 1876-77*, (London: Taylor & Francis, 1876), 31.

²⁹ *ibid.*

³⁰ Hill, *op. cit.*, (24), f.5.

³¹ Olaus Henrici, *Elementary Geometry. Congruent Figures*, (London: Longmans, Green, and Co., 1879), xv.

geometrically-oriented than either of his predecessors and a radical departure from the analytically-biased Cambridge-style course previously taught. Following its introduction into the University College syllabus, Henrici remained as professor of pure mathematics for another four years before transferring to the chair of applied mathematics and mechanics, taking his new course with him. The applied section of that course will therefore be discussed in the following section, but first we must investigate the teaching of applied mathematics at University College following the creation of the chair in 1868.

6.2 The Applied Side

6.2.1 The Goldsmid chair

While the chair of pure mathematics flourished, the department of applied mathematics and mechanics was very much the poor relation. On its establishment in 1868, Benjamin Theophilus Moore (1830-1899) had been appointed professor. A graduate and fellow of Pembroke College, Cambridge, (eighth wrangler in 1856), Moore had had a varied and distinguished teaching career, being a mathematical master at Harrow in the 1850s and professor of mathematics at the Royal Staff College at Sandhurst from 1859 to 1864.³² However, at University College his average class size never rose above nineteen³³ and, since this was still a time when a professor's income was totally dependent on his fees, Moore found himself in a position where the earnings were scarcely adequate to justify the work involved.

Consequently, at the end of August 1870, he wrote to the college secretary, John Robson,³⁴ intimating that he thought it unlikely that he would be able to retain his professorship during the forthcoming session.³⁵ However, much to his surprise, he was informed that, since he had not given the council sufficient time to find a replacement, he was contractually obliged to retain the chair for another year. In his reply, Moore protested against this rule, of which he was previously unaware, giving a recent counter-example: "Professor Hirst, I may remind you, was released during the full work of the Session, & therefore it is hardly reasonable to say that notice ought to be given on the first of June. I *could* not give it then because I was uncertain

³² John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 4, 450.

³³ Ker, *op. cit.*, (10), 60.

³⁴ Robson had succeeded Charles C. Atkinson in this position in July 1867.

³⁵ UCL College Correspondence, Benjamin Moore to John Robson, 22 Aug. 1870.

altogether. Now I am almost certain I cannot go on with lectures in October, & therefore write to you on the subject."³⁶

Since the college council was not scheduled to meet until after the beginning of the new session, the matter was passed directly to its President, George Grote (1794-1871). He wrote to Robson, "It is clear that Mr. Moore has acted in direct contravention of the obligation by which he was bound by the Bye-Laws, as to time of resignation. But as he has determined to neglect this obligation, I fear the College has no means of enforcing performance: and even if there were means, I doubt whether in this particular case we should gain by exerting them."³⁷ His recommendation was that Moore be requested to formally resign and that discrete inquiries be made from Hirst, Carey Foster and other professors, to find a temporary replacement as quickly as possible, "for this is an uncomfortable occurrence for U.C."³⁸

Moore's resignation was duly forthcoming, although his acknowledgement of Robson's letter of acceptance shows that he was clearly surprised and offended that his departure had caused so much controversy. In particular he resented "that you should use the words 'most unsatisfactory & unpleasant' in speaking of the manner of my resignation... When I found that I could not well retain my Chair, I wrote to you on the subject not doubting that there was plenty of time to appoint my successor during the Vacation... The President, you inform me, has accepted my resignation and therefore I am at a loss to understand you when you speak of the 'sudden abandonment of my chair'. *I have not abandoned my chair at all,...*and if inconvenience arises from my retirement, I must remind you that the decision was made by the President and not by myself. I did all I could to *avoid* inconvenience."³⁹ On this acrimonious note, Moore's connection with University College was terminated.

Meanwhile, the college was having no success in finding a suitable replacement to teach Moore's classes. On 12 September, Grote was enquiring whether it would be possible "for Mr. Percy Harding, who is now Assistant to Professor Enrici [sic], to undertake, besides, the additional duty of teaching Moore's class until Christmas?"⁴⁰ - but the answer was apparently negative. One month later, a new appointment was still no nearer. Grote complained: "It is vexatious that no temporary substitute, from without the College, can be found for Mr. Moore. But since such is the fact, I see no

³⁶ *ibid*, 1 Sept. 1870.

³⁷ *ibid*, George Grote to John Robson, 7 Sept. 1870.

³⁸ *ibid*.

³⁹ *ibid*, Benjamin Moore to John Robson, 24 Sept. 1870.

⁴⁰ *ibid*, George Grote to John Robson, 12 Sept. 1870.

alternative except to avail ourselves of Professor Henrici's good offices for the time, as far as they will go, until we can appoint a new Professor in December next."⁴¹ A temporary arrangement was thus made whereby Henrici, in addition to his regular duties in the pure chair, delivered lectures in applied mathematics during the first term of the 1870-71 session.

However, by the beginning of 1871, a new professor had still to be found. Indeed, despite issuing the usual advertisements, the college council were in the predicament of being unable to find a successor willing to undertake a job with such poor financial prospects. Furthermore, by the time of their annual report in February, they were forced to admit "that Mr. Moore's resignation, which was not in accordance with the provisions of the Bye-Laws on this subject, has had an injurious influence upon the Classes of Applied Mathematics and Mechanics".⁴² The situation was clearly very serious, resulting in a special committee of the council being set up to discuss the problem and receive specialist advice. One of the experts consulted was Thomas Archer Hirst, whose diary for 18 March 1871 records his attendance at a "Committee of Council of University Coll. (with Sylvester) about Professorship of Mixed Mathematics".⁴³

After several meetings, the committee came to the conclusion "that there was little probability of securing the services of a thoroughly competent Professor of Applied Mathematics and Mechanics unless the emoluments of the Chair could be increased considerably beyond the amount likely to be derived from fees."⁴⁴ Since the college's financial situation was still far from secure and its funds were in no way sufficient to adequately endow the position, this decision could have resulted in the abolition of the applied chair altogether. Fortunately however, the dilemma was resolved by the intervention of a committee member, Sir Francis Goldsmid, who, in May 1871, offered to guarantee an endowment of £200 per annum in addition to the income of the chair.⁴⁵ Initially sanctioned as a five-year experiment, this donation resulted in the

⁴¹ *ibid*, 12 Oct. 1870.

⁴² *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1871*, (London: Taylor and Francis, 1871), 17.

⁴³ Brock and MacLeod, *op. cit.*, (7), 1896.

⁴⁴ *University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 28th February 1872*, (London: Taylor and Francis, 1872), 14.

⁴⁵ Council Minutes, 6 May 1871; *Memoir of Sir Francis Henry Goldsmid*, 2nd ed., (London: Kegan Paul, Trench, and Co., 1882), 73-74.

inauguration of the Goldsmid Chair of Applied Mathematics and, very possibly, saved applied mathematics at University College from early extinction.⁴⁶

6.2.2 William Kingdon Clifford

With this new incentive the council were able to secure the services of possibly the most promising young British mathematician of the time, William Kingdon Clifford (1845-1879). Educated at the rival King's College London from the age of fifteen, Clifford had left that institution with distinctions not only in mathematics, but also in classics, modern history and English literature. Moving to Trinity College, Cambridge, in October 1863, after three years he had already attracted the attention of prominent figures in the British mathematical community (see Section 5.2.4). Indeed, among members of the London Mathematical Society, there was much speculation about how he would perform in the Tripos, Cayley writing to Hirst in January 1867 that "I saw Clifford just after the examination, his own impression as to his place is 6th or 7th, from which I infer that it will be at any rate 5th."⁴⁷ Four days later, when the results were announced, he wrote again: "It is a good deal better than I expected - Clifford is second..."⁴⁸

In addition to the second wranglership, Clifford also obtained the second Smith's prize of his year, receiving a fellowship at Trinity in 1868.⁴⁹ Three years later, on hearing of its endowment, he applied for the vacant chair at University College. In electing him to the professorship, the college council reported that they had "received evidence of the strongest kind from some of the most eminent mathematicians of Mr. Clifford's remarkable genius for and attainments in the highest branches of Pure and Applied Mathematics; so that in appointing him to the Professorship they entertained a firm conviction that he would maintain the reputation of the College, and promote the prosperity of its Faculty of Science".⁵⁰ His appointment to the applied chair at University College was his first and, as it turned out, his last academic position.

During his period in London, he produced many publications on various areas of mathematics, especially geometry, where he undertook significant work in the relatively new subject of non-Euclidean geometry. His research in this area also contributed to contemporary philosophical debates, regarding geometry as a physical

⁴⁶ Ker, *op. cit.*, (10), 60-61. The arrangement was renewed in 1876, and on Goldsmid's death in 1878, he left £40,000 to the college, from the interest of which an annual endowment of £200 was paid to the professor.

⁴⁷ LMS Papers, Arthur Cayley to Thomas Archer Hirst, 21 [Jan. 1867].

⁴⁸ *ibid*, 25 Jan. 1867.

⁴⁹ Venn, *op. cit.*, (32), 2, 67.

⁵⁰ *op. cit.*, (44), 15.

science whose axioms are based on experience, thus opposing Kant's *a priori* view of geometrical knowledge. His speculations about the variable curvature of physical space were later to be of major importance in the development of the theory of relativity early in the twentieth century, thereby ensuring an enduring reputation among later mathematicians.

Clifford seems destined to remain one of the historic figures of mathematics. To this day investigators are continually rediscovering in his works the origin or the suggestion of what have since been far-reaching developments. His thought ran greatly upon what may be called the philosophy of mathematics, and indeed his early training...fitted him peculiarly for this task. He was one of the pioneers, so to speak, of non-Euclidean space, and some of his conceptions of space are appealed to nowadays by the followers of Einstein.⁵¹

In addition to his outstanding contributions to the fields of geometry and philosophy, Clifford was an excellent lecturer, giving enjoyable and (apparently) intelligible talks on abstruse topics, with only a few brief notes. Indeed, it was claimed that much of his best work was actually spoken before it was written: "He gave most of his public lectures with no visible preparation beyond very short notes, and the outline seemed to be filled in without effort or hesitation. Afterwards he would revise the lecture from a shorthand-writer's report, or sometimes write down from memory almost exactly what he had said."⁵²

It seems that he enjoyed this duty far more than testing the students on what he had taught them. "The worst of these examinations," he is reported as saying, "is that you have to think what to ask the fellows before you come in, whereas, when you lecture you need not think at all."⁵³ Whatever his own opinion may have been, he left a profound impression not only on those who heard him lecture, but also on the scientific world at large. J.W.L. Glaisher later wrote: "...the word 'fascinating' could truly be applied to his oral communications. ... So much, however, depended on Clifford's manner and his imagery, his gentle voice, rapid diction, and clever way of putting familiar ideas, that it was afterwards difficult to recall what it was that had made so much impression at the time."⁵⁴

⁵¹ Louis N. G. Filon, "Notes for the History of the Department of Applied Mathematics", MS (1919), University College Archives, Materials for the history of UCL, Mem. 2A/18, ff.3-3a.

⁵² Leslie Stephen and Frederick Pollock (eds.), *Lectures and Essays. By the late William Kingdon Clifford*, (London: Macmillan and Co., 1879), vol. 1, 8.

⁵³ Negley Harte and John North, *The World of UCL 1828-1990*, (London: UCL, 1991), 106.

⁵⁴ J. W. L. Glaisher, Notes on the early history of the Society, *Journal of the London Mathematical Society*, **1** (1926), 51-64, p.62.

Corroboration of this intriguing characteristic is given by a fellow student from Trinity, who recalled that Clifford's method of teaching was evident in his conversations on mathematical and scientific subjects even as a student:

In the analytical treatment of statics there occurs a proposition called Ivory's Theorem concerning the attractions of an ellipsoid. The textbooks demonstrate it by a formidable apparatus of coordinates and integrals, such as we were wont to call a *grind*. On a certain day in the Long Vacation of 1866, which Clifford and I spent at Cambridge, I was not a little exercised by the theorem in question, as I suppose many students have been before and since. The chain of symbolic proof seemed artificial and dead; it compelled the understanding, but failed to satisfy the reason. After reading and learning the proposition one still failed to see what it was all about. Being out for a walk with Clifford, I opened my perplexities to him; I think that I can recall the very spot. What he said I do not remember in detail, which is not surprising, as I have had no occasion to remember anything about Ivory's Theorem these twelve years. But I know that as he spoke he appeared not to be working out a question, but simply telling what he saw. Without any diagram or symbolic aid he described the geometrical conditions on which the solution depended, and they seemed to stand out visibly in space. There were no longer consequences to be deduced, but real and evident facts which only required to be seen.⁵⁵

Clifford was one of the first to protest the analytical bias of the Cambridge mathematical system. Like De Morgan before him, he aimed to teach students not the analytical solution of a problem, but how to think for themselves. His applied course at University College (like Henrici's pure course, with which it ran parallel) was far more geometrical than those of his predecessors; his lectures introduced to England the graphical and geometrical methods of Möbius, Culmann, and other German geometers.⁵⁶ Clifford thus shares the credit with Henrici for introducing graphical statics to English university education.

Although an enthusiastic athlete, Clifford was afflicted with a fragile constitution "in which nervous energy and physical strength were unequally balanced".⁵⁷ He drove himself relentlessly, both mentally and physically, often depriving himself of sleep by writing papers and lectures during marathon sessions which lasted through the night. The result was that, after a few years, his health began to decline. By 1876 he had developed a pulmonary disorder which resulted in a six month leave of absence from his professorial duties, during which time he journeyed to Algeria and Spain. After

⁵⁵ Alexander MacFarlane, *Lectures on Ten British Mathematicians of the Nineteenth Century*, (London: Chapman and Hall, 1916), 81.

⁵⁶ *D.N.B.*, **11**, 82-85, p.84.

⁵⁷ MacFarlane, *op. cit.*, (55), 81.

about eighteen months of improved health, he was again obliged to seek sanctuary abroad during the summer of 1878. He died in Madeira in March 1879 having not yet reached the age of thirty-four.

During the period of Clifford's illness, and for the remainder of the 1879-80 session, applied mathematical tuition was supplied by Henrici's pure mathematics department.⁵⁸ In the meantime, the council appointed a committee to discuss future arrangements for applied mathematical teaching. Once again, the erstwhile Professor Hirst was recruited for consultation and, at a meeting on 20 March 1880, he proposed "that the chair of Applied Mathematics (Clifford's Chair) should be restored with an endowment of £200 (I afterwards induced Henrici to accept this chair in lieu of his own unendowed chair of mathematics)".⁵⁹ So, at the beginning of the next session, Henrici transferred from the pure chair to that of applied mathematics.

In his new position, Henrici continued to introduce further reforms and innovations into the syllabus. The first of these was the transferral of his course on projective geometry and graphical statics, which was adapted to meet the needs of his applied mathematical students, now consisting of the following elements:

Areas of Plane Figures and their Transformation; Similar Figures. Graphical Calculations: Addition, Multiplication and Integration by aid of Vector- and Link-polygons. Graphical Statics and Applications. Parallel, Central, and Orthographic Projection, with Applications to Geometrical Drawing and to Graphical Addition, Multiplication and Integration in three dimensions. Determination of Volumes and of Centres of Gravity. Projective Rows and Pencils; Cross-Ratios. Principle of Duality. Theory of Conics, Cones, and Ruled Quadric Surfaces. Involution; Imaginary Elements and Circular Points in the Plane. Application of Moments of Inertia of Plane Figures.⁶⁰

The adaptation of this course for an applied mathematical syllabus also marked the introduction of vectors into English mathematical teaching, bringing in further continentally-inspired methods and reinforcing the geometrical style of instruction favoured by Clifford. It is not surprising that, in the decade after Henrici's departure from University College, it was remarked that "not the least of his many great services to the teaching of Applied Mathematics at University College has been to free the chair from the trammels of the old Cambridge analytical school of mathematics".⁶¹ He

⁵⁸ UCC, Nos. AM/C/19 and AM/C/51.

⁵⁹ Brock and MacLeod, *op. cit.*, (7), 2098.

⁶⁰ *University College, London. Calendar. Session 1883-84*, (London: Taylor and Francis, 1883), 62.

⁶¹ Ker, *op. cit.*, (10), 61.

remained as professor of applied mathematics for another four years before being lured away in 1884 to take a similar chair at the new Central Technical Institute in South Kensington (see Chapter 7). There, as at University College, he would maintain his reputation as an effective and innovative teacher, his success corroborated by student accounts of "the singular lucidity of his teaching"⁶² and the "masterly ease and freedom"⁶³ of his exposition.

6.3 Towards the Twentieth Century

6.3.1 The 1884 competition

Henrici's successor in 1880 in the chair of pure mathematics had been one of his most successful students, and in fact was also the first University of London graduate to hold the position. Richard Charles Rowe (1853-1884) had entered the college in January 1872, receiving an exhibition on his matriculation as well as the University scholarship in mathematics after graduating in 1875. By 1877, he had obtained the degrees of B.A., B.Sc. and M.A., prompting a comment from Henrici, "who examined him on all these occasions except Matriculation ... that of all the Candidates who he has examined at the University of London Mr Rowe was one of the very few who have made upon him the impression that he was dealing with a man who possessed real Mathematical power".⁶⁴

With such impressive mathematical abilities, it was natural that Rowe should proceed to Cambridge, entering Trinity College in 1873. In 1878, a year after graduating as third wrangler, he was elected to a fellowship, during which time it would appear that his mathematical talents became known to the elder mathematicians of his college. His election to the professorship at University College was no doubt especially due to the mathematical eminence of two of his referees. One was J.W.L. Glaisher who, like Henrici, had not only taught and examined Rowe in mathematics, but also had "never examined anyone whose solutions were so good or who showed so much ability and skill in the higher parts of pure mathematics".⁶⁵ The other was none other than Arthur Cayley, whose testimony alone must have been highly beneficial to Rowe's candidature:

⁶² Hill, *op. cit.*, (23), xlix.

⁶³ Walter Raleigh, *The Faith of England. An Address to the Union Society of University College, London, delivered March 22, 1917*, (Oxford: Clarendon Press, 1917), 4.

⁶⁴ UCC, No. AM/C/57(ii), Report of Committee on the applications for the Chair of Pure Mathematics, July 1880, f.4.

⁶⁵ *ibid*, f.4a.

My acquaintance with Mr Rowe as a Mathematician is derived from the very able dissertation on Abelian Integrals (being a reproduction and discussion with developments of his own, of the theory contained in Abel's great Memoir of 1826) sent in by him at the Trinity Fellowship Examination two years ago, and which he has, at my request, recently communicated to the Royal Society. I have from this a high opinion of his knowledge and abilities, and cordially recommend him as fitted for the Professorship of Pure Mathematics at University College, London, for which he is a Candidate.

Munich 21st June 1880

A. Cayley.⁶⁶

On returning to his old college, the new professor's academic potential showed every evidence of being fulfilled as he proved himself to be a very able research-level mathematician. His principal work while in London was a paper on Abel's Theorem, published in the *Philosophical Transactions of the Royal Society* in 1881.⁶⁷ However, he did not stay long enough to make any major impression on the teaching of the subject, resigning his chair in 1884 to take up the post of assistant tutor at Trinity College. The resignation, we are told, "was received with universal regret, on account not only of his reputation as a mathematician but of the singular attraction of his personal character which had made itself felt both among colleagues and pupils".⁶⁸ Sadly, however, Rowe's promising career was cut short before he could enter into his Cambridge duties. He died on 21 September 1884, a few weeks before the start of the academic year.⁶⁹

Yet despite the disappointment of losing such a capable mathematician, the competition to determine his successor proved to be an extremely fruitful event for both pure and applied mathematics at the college. Indeed, in terms of contests for the mathematical chair, it is arguably the most interesting since that of 1827-28. Up to this point, the council's choice of a new mathematical professor had usually been constrained either by a scarcity of applications or by a general deficiency in the candidates' general quality. In 1884, for perhaps the first time in the history of mathematics at University College, the overall calibre of the candidates was so impressive that the council were faced with several competitors, all of whom would have been worthy of the appointment. Of a total of eleven applicants, four were of noticeably superior ability - and two of these were quite exceptional.

⁶⁶ *ibid.*

⁶⁷ Richard Charles Rowe, Memoir on Abel's Theorem, *Philosophical Transactions of the Royal Society*, **172** (1881), 713-750.

⁶⁸ Hill, *op. cit.*, (24), f.6.

⁶⁹ Venn, *op. cit.*, (32), 5, 369.

The first was Arthur Buchheim (b.1859), an Oxford-trained mathematician who, after obtaining a first-class degree in 1880,⁷⁰ had spent the majority of the following year in Leipzig, where he had joined Felix Klein's mathematical seminary. His wide range of testimonials included one from Klein himself, indicating a high opinion of his knowledge and originality. Another letter on his behalf, from Oxford's Savilian Professor, Henry Smith, who had died the year before the competition, referred to him as "a young mathematician of the highest promise", claiming that "if life and health be given to him, he will one day become a really eminent mathematician and that any Institution, with which he may be connected as Professor, will have cause to be proud of him".⁷¹

Joseph Larmor (1857-1942) was an Irish mathematician who, after studying at Queen's College, Belfast, in the early 1870s, had entered St. John's College, Cambridge, graduating as the Senior Wrangler and first Smith's prizeman of 1880.⁷² In that year he had received the professorship of natural philosophy at Queen's College, Galway, from where his application was made. He too provided ample evidence of his mathematical abilities in the form of mathematical papers and testimonials from both Cambridge and Ireland. E. J. Routh, his tutor while at Cambridge, predicted future distinction in mathematical authorship, while in a letter recommending his appointment to the chair at Galway, George Stokes described him as "one who has a deep and varied knowledge of the principles of Physics".⁷³ Furthermore, he also provided evidence of being "a careful, painstaking and successful teacher, liked by his pupils, and a man of considerable strength of character".⁷⁴

The third significant applicant was also destined to become an outstanding figure in the history of mathematical science: Karl Pearson (1857-1936). Educated at University College School from 1866 to 1873,⁷⁵ he had proceeded to King's College, Cambridge, in 1875, graduating as third wrangler in the Tripos of 1879.⁷⁶ Following his election to a college fellowship, he moved to Germany in 1880, studying philosophy and law at Heidelberg before returning to England the following year. During the first half of 1881 he undertook the duties of the professor of mathematics at King's College London, also standing in for Professor Rowe at University College

⁷⁰ Joseph Foster, *Alumni Oxonienses 1715-1886*, 1, (London: Joseph Foster, 1888), 182.

⁷¹ UCC, No. AM/C/141, Report on the Applications for the Chair of Mathematics at University College, London, 7 March 1884, f.6.

⁷² Venn, *op. cit.*, (32), 4, 99.

⁷³ *op. cit.*, (71), f.8.

⁷⁴ *ibid.*

⁷⁵ Temple Orme, *University College School, London. Alphabetical and Chronological Register for 1831-1891*, (London: H. Walton Lawrence, 1892), 188.

⁷⁶ Venn, *op. cit.*, (32), 5, 64.

during the spring term of 1884. In both cases, it was noted that he was "especially esteemed by his students for the clearness of his teaching".⁷⁷

His mathematical ability was highly rated by his referees, especially by his former Cambridge coach, E. J. Routh, who believed that "he will not merely be an efficient teacher, but will be led on to distinguish himself by some original work".⁷⁸ Yet, while his two published mathematical papers were described as being "equal to work published by men whose whole attention is given to mathematics",⁷⁹ there was also evidence to suggest that Pearson's scholarly achievements were not limited to mathematics alone; indeed, one of his referees described him as a "man of exceptionally wide and varied culture and an accomplished scholar in other fields of learning besides that in which he won high honours at Cambridge".⁸⁰ This claim was confirmed by the fact that, up to this point, in addition to his mathematical papers, Pearson had also written articles on German history, literature and philosophy, as well as studying to become a lawyer, having been called to the Bar in 1881.

Perhaps for this reason, it is not surprising that, in taking the step of applying for the mathematical professorship at University College, he was widely encouraged from all sides of the college's academic spectrum:

Professor Beesly, just because I had lectured to revolutionary clubs, Professor Croom Robertson, just because I had written on Maimonides in his journal *Mind*, Professor Alexander Williamson just because I had published a memoir on atoms, and Professor Henry Morley, just because I had attended and criticised lectures of his on the Lake Poets, pressed me to be a candidate for the Chair of Mathematics!⁸¹

The final important applicant was Micaiah John Muller Hill (1856-1929). Hill had been a student of Henrici and Clifford at University College at the same time as Richard Rowe, entering in 1872. On taking his B.A. degree in 1874, he had come first in the mathematical honours list, winning the gold medal at the University of London M.A. examination two years later.⁸² By this time he had proceeded to Peterhouse, Cambridge, being elected to an open scholarship in 1875. While there he befriended Karl Pearson, graduating in the same year, one place lower, as fourth wrangler and

⁷⁷ *op. cit.*, (71), f.10.

⁷⁸ *ibid*, f.9.

⁷⁹ *ibid*.

⁸⁰ *ibid*.

⁸¹ Harte and North, *op. cit.*, (53), 105.

⁸² Louis N. G. Filon, Obituary Notice of M. J. M. Hill, *Journal of the London Mathematical Society*, 4 (1929), 313-318, p.313.

joint first Smith's prizeman.⁸³ Following the death of Clifford in 1879, he had briefly returned to teach mathematics at University College as Henrici's assistant,⁸⁴ before being appointed professor of mathematics at the recently-established Mason's College, Birmingham, in 1880.

Hill's period at Birmingham saw the publication of his earliest research work. His particular forte at this time was hydrodynamics, several of his papers dealing with the subject, and, in particular, the generalisation of hydrodynamical equations for n -dimensional space. But his abilities extended over a wide mathematical area so that, by the time of his application to University College, his published research comprised six papers on both pure and applied mathematical topics in journals including the *Transactions of the Cambridge Philosophical Society* and the *Philosophical Transactions of the Royal Society*. These were spoken of by referees such as Stokes, Todhunter, Routh and Cayley as "showing intimate acquaintance with some of the more abstruse branches of mathematics, combined with much originality and great power of generalization".⁸⁵

From the evidence submitted to the council on behalf of the four major candidates, it was clear that any one of them would have been a worthy addition to the college's already impressive inventory of distinguished professors of mathematics. However, only one professorship was available, so a decision had to be made. The first of the four to be eliminated was Buchheim, since he was somewhat younger than his fellow candidates and had no direct experience of professorial work. Similarly, Larmor, although undoubtedly a mathematician of experience and ability, was rejected on the grounds of his being more of an applied than a pure mathematician. However, this rejection was far from injurious to his future career. The following year, he returned to Cambridge to take an appointment as a university lecturer, succeeding Stokes as the Lucasian professor of mathematics in 1903. In this position he would establish his reputation as an outstanding theoretical physicist with his work in electromagnetism and thermodynamics, for which he was knighted in 1909.⁸⁶

The council's real dilemma was how to choose between Hill and Pearson. Both had provided abundant testimony to the extent of their mathematical powers, demonstrating their extensive qualifications for the post in question. However, it was reported that "although there is much more to be said in favour of Mr Hill as a

⁸³ Venn, *op. cit.*, (32), 3, 372.

⁸⁴ UCC, No. AM/C/19, 8 March 1879; No. AM/C/51, 3 March 1880.

⁸⁵ *op. cit.*, (71), f.11.

⁸⁶ *D.N.B. 1941-1950*, 480-483.

mathematician, the Committee were for some time in doubt whether this would not be more than compensated for by the rigour and freshness of Mr Pearson's mental and physical powers".⁸⁷ Nevertheless, despite this slight reservation, Hill's experience in a permanent mathematical position proved to be a substantial advantage, while Pearson's wide-ranging skills, though impressive, did not provide the selectors with "much evidence that his powers are likely to be permanently employed in the furtherance of mathematics".⁸⁸ Thus, in March 1884, after one of the most fiercely contended competitions for a mathematical chair since the college's foundation, M. J. M. Hill was appointed the new professor of pure mathematics.⁸⁹ He was to hold the position until 1923.

However, all was not lost for Karl Pearson. At a meeting of the Faculty of Science on 5 May 1884, a mere two months after Hill's appointment to the pure chair, Professor Henrici announced his intention of resigning the professorship of applied mathematics. In view of the short interval which had passed since the last competition, it was decided to select one of the rejected applicants for the chair of pure mathematics. Of these candidates, Pearson had been prominent by virtue of his exceptionally wide-ranging abilities. Moreover, the Faculty noted that "further experience of the work of Mr Pearson in the College has shewn the members of the Faculty that it would be so great an advantage to the College to retain him on the staff of its Teachers that they suggest that the Senate should recommend the Council to appoint him in the event of his application, to the Professorship of Applied Mathematics".⁹⁰

This opinion was not unique to the college's professoriate: other interested parties also favoured the installation of Pearson to the applied chair. For instance, shortly after the above meeting, Thomas Archer Hirst recorded a conversation with Henrici concerning the arrangements for appointing his successor, during which he had enquired "if Carl [sic] Pearson (a 3rd Wrangler), who has been taking Roe's [sic] classes since Christmas very successfully, could not be induced to become a candidate".⁹¹ Whether the favoured competitor would have required much persuasion to re-apply is not known, but, in any case, his application was received on 26 May 1884 as one of eleven bids for the position. Other candidates included Buchheim and Larmor, as well as Edward Thornton Littlewood (1859-1941), the father of J. E. Littlewood (1885-1977).

⁸⁷ *op. cit.*, (71), f.13.

⁸⁸ *ibid.*

⁸⁹ Council Minutes, 8 March 1884.

⁹⁰ UCC, No. AM/C/146, Report of the Faculty of Science adopted by the Senate of University College, May 7 1884, ff.1-2.

⁹¹ Brock and MacLeod, *op. cit.*, (7), 2146.

In offering his candidature once again, Pearson supplemented his previous application with "one or two letters from gentlemen who have had occasion to see something of my mathematical work on the physical side".⁹² One of these was a further testimonial from E. J. Routh, who emphasised the breadth of Pearson's knowledge of applied mathematical topics, adding that the "great weight given to these in the examination and his own distinguished position in that Tripos prove how successful his studies have been".⁹³ The other was from William Burnside, soon to acquire a distinguished reputation as both a pure and applied mathematician, and in whose opinion "Mr Karl Pearson has a distinguished future before him in devoting his energies to the physical applications of Mathematics".⁹⁴

Due largely to the candidature of candidates such as Buchheim and Larmor, the competition for the professorship of applied mathematics was as distinguished as that for the pure chair two months previously. However, because of the professorial resolution mentioned above, the result was, in effect, a foregone conclusion. Pearson's election to the professorship was virtually ensured as soon as he applied, and endorsed soon after.⁹⁵ So began his connection with University College, an association which was to last for nearly half a century, first as professor of applied mathematics and mechanics from 1884 to 1911, then as the country's first professor of applied statistics and eugenics from 1911 to 1933. Thus, for the remaining years of the nineteenth century, Karl Pearson and M. J. M. Hill were in joint control of the mathematical tuition administered at University College. This chapter will conclude with a brief survey of the work of the former in the applied chair and the latter in the department of pure mathematics.

6.3.2 Hill and Pearson

It will be remembered that the positions to which the two men had been appointed were very different in terms of their respective stipends. Pearson was in the rare position of occupying an endowed chair, while Hill, in common with most of his fellow professors, still relied on his share of student fees. This situation provided "a strong inducement to make one's teaching popular rather than profound, a temptation fortunately resisted in most cases, certainly in the case of Hill".⁹⁶ As with all his immediate predecessors, Hill's income was enough to enable him to employ an

⁹² UCC (Applications), Karl Pearson to Council, 26 May [1884].

⁹³ *ibid*, Edward J. Routh to Council, 24 May 1884.

⁹⁴ *ibid*, William Burnside to Council, 24 May 1884.

⁹⁵ Council Minutes, 7 June 1884.

⁹⁶ Filon, *op. cit.*, (82), 314.

assistant, although the vast majority of undergraduate teaching was still undertaken by the professor himself, work which he "performed with unflagging energy and zeal, and an unselfish devotion which won him the affection and admiration of generation after generation of students".⁹⁷

Despite his employment of an assistant, a Mr. H. J. Harris, to teach his lowest class, it appears unlikely that Hill's workload was substantially reduced. On the contrary, judging from the following syllabus, it seems more probable that, due to an increase in his classes, it actually increased.

A. LOWER JUNIOR CLASS: Arithmetic, Algebra and Geometry.

B. JUNIOR CLASS: Elementary Mathematics (inc. quadratic equations, circle, sphere and cylinder, and elements of plane co-ordinate geometry).

C. SENIOR CLASS: Algebra (Binomial Theorem to Complex Numbers); Plane Trigonometry (to De Moivre's Theorem); Geometrical Conics; Elementary Projective Geometry (up to Theorems of Pascal and Brianchon); Plane Co-ordinate Geometry (properties of Conic Sections).

D. SENIOR CLASS: Differential and Integral Calculus (to integration by substitution and integration by parts).

E. SENIOR CLASS: Spherical Trigonometry.

F. HIGHER SENIOR CLASS: Advanced Algebra and Trigonometry; Differential and Integral Calculus; Differential Equations; Laplace's Functions; Bessel's Functions; Geometry of Space; the Calculus of Variations; the Calculus of Finite Differences.

At the research level, Hill's work concentrated on three main topics: hydrodynamics, differential equations, and the theory of proportion. In the first (from 1883-94), he developed the theory of cylindrical vortices of finite section moving in an infinite fluid and published the solution for the well known spherical vortex, now known as Hill's Equation. Between 1888 and 1893, he investigated the various loci connected with first order differential equations and their complete primitives, obtaining many new and important results on the more general question of loci of singular points. However, it was the critical reappraisal of the fifth and sixth books of Euclid which was to dominate his later mathematical research. Inspired by problems experienced when teaching students the theory of proportion, as well as the related studies of Augustus De Morgan, "of whom he always spoke with the greatest admiration",⁹⁸ Hill's work succeeded in simplifying Euclid's approach for the beginner.

⁹⁷ *ibid.*

⁹⁸ *ibid.*, 316.

Unfortunately, coinciding as it did with the period of Euclid's expulsion from the classroom, this achievement was never properly appreciated.

Described as "one of the most commanding personalities"⁹⁹ of the college, as a teacher Hill was skilful, methodical, and extremely popular. Infinitely patient, "he possessed that rare quality, which students so keenly appreciate, of never slurring over difficulties: time spent on making a demonstration perfect was always to him time well spent".¹⁰⁰ Louis Napoleon George Filon (1875-1937), one of Hill's students and later the college's professor of applied mathematics in succession to Pearson (1912-1937), remembered "sending up to him a solution which, alas! meandered through as many pages as it should have taken lines, arriving at the desired result by a singularly laborious and inelegant process. Hill read patiently and carefully every line, and in the end his only (and characteristic) comment was that it was a 'very courageous' solution!".¹⁰¹

Hill's faithful and conscientious service in the unendowed chair of pure mathematics was rewarded halfway through his tenure, just after the turn of the century. In 1902, the wealthy American aristocrat William Waldorf Astor (1848-1919), later to become the first Viscount Astor, donated £20,000 to the college "for the endowment of existing unendowed Professorships".¹⁰² It was eventually decided to use some of the money to endow the chair of pure mathematics, the council resolving

That the emoluments of the Chair of Pure Mathematics be £700 per annum, and consist

- a. As to £300 (less Income Tax) of income from the Astor Endowment.
- b. As to £400 of a fixed stipend of the Department.¹⁰³

It was also decided "That the Council grant, after consultation with the Professor of Pure Mathematics, such further sum for the remuneration of Assistants as they shall from year to year think fit".¹⁰⁴ The creation of the Astor chair not only resulted in an increase in Hill's yearly earnings, but, in his words, freed him "from the anxiety necessarily attaching to an income, the amount of which depends on the fluctuating

⁹⁹ Hugh Hale Bellot, *University College London 1826-1926*, (London: University of London Press, 1929), 390.

¹⁰⁰ Filon, *op. cit.*, (82), 317.

¹⁰¹ *ibid.*

¹⁰² *University College, London. Report of the Council, financial statements, and other documents to be presented to the Members of the College at the Annual General Meeting on Wednesday, 25th February, 1903*, (London: Taylor and Francis, 1903), 22.

¹⁰³ Council Minutes, 28 July 1902.

¹⁰⁴ *ibid.*

receipts from Students' fees".¹⁰⁵ For the first time since the college's foundation, the professor of pure mathematics was guaranteed an annual salary; and unlike the previous guarantee made to De Morgan seventy years earlier, this one was based on a secure financial investment which would not be withdrawn. Indeed, the Astor Professorship of pure mathematics, like its applied counterpart, survives to the present day.

Meanwhile, in the Goldsmid chair, Pearson continued to run the course very much on the geometrical lines laid down by his two immediate predecessors. In his term of office, the graphical statics course was complemented by a new course on graphical dynamics, together with the graphical theory of beams and arches. He also devoted a large portion of his higher undergraduate course to the theory of elasticity, with which much of his research work was concerned during the 1880s. His standing as a research-level applied mathematician was complemented by a reputation as one of "the most influential university teachers of his time".¹⁰⁶ It is reported that in his lectures he took "great pains to be intelligible and could hold a large audience either of students or of merely casual hearers who were without special interest in his topics".¹⁰⁷

Not content with his duties at University College, in 1890 he applied for and was appointed to the professorship of geometry at Gresham College.¹⁰⁸ This post, which he held in tandem with his University College chair until 1894, enabled him to give popular lectures on subjects of his choosing. Among the subjects he chose were graphical statistics and probability theory, on which he lectured "with that wealth of illustration, diagrammatic and arithmetical, which characterized all his popular lectures".¹⁰⁹ During the 1890s, deeply influenced by the work of both Francis Galton and W. F. R. Weldon, Pearson became increasingly interested in applied statistics and the correlation of biological and sociological data and, while he continued to teach and research subjects within the scope of his chair, it was perhaps inevitable that his interests would eventually filter down to his college teaching.

The first results of Pearson's new work were seen at the undergraduate level in 1894, when a subject which, it was asserted, "will one day have a widely recognised

¹⁰⁵ UCC, No. AM/D/199, M. J. M. Hill to Council, 1 Aug. 1902.

¹⁰⁶ *D.N.B. 1931-1940*, 683.

¹⁰⁷ *ibid.*

¹⁰⁸ M. Eileen Magnello, Karl Pearson's Gresham lectures: W. F. R. Weldon, speciation and the origins of Pearsonian statistics, *British Journal for the History of Science*, **29** (1996), 43-63, p.47.

¹⁰⁹ *op. cit.*, (106), 682.

importance"¹¹⁰ was introduced into the University College syllabus. In that year, one hour's weekly tuition was provided on the theory and practice of statistics. Subjects covered included frequency curves, errors of observation and measurement, compound and skew distributions, means and averages, and correlation, with data for analysis being taken from thermometer and barometer readings, disease statistics and skull measurements. However, although it was claimed that the course "will be found of value to those desiring to study Animal Variation, to deal with the Errors of Physical Observations, or to become Actuaries",¹¹¹ the course only ran for one year - perhaps due to a lack of such students.

Then, in 1898, it was announced that "provision, if required, will be made for four hours' work ... weekly - two hours Lectures and two hours Practical Class ... [on the] Mathematical Theory of Statistics".¹¹² This comprised an elementary course, in which topics included the general theory of statistics, normal and skew variation, and normal correlation, and an advanced course on the quantitative theory of heredity. As before, teaching involved using actual statistical data to calculate various types of statistical measurements and coefficients using tables and mechanical calculators. However, unlike its short-lived predecessor, this course was to remain on the applied mathematical syllabus, constituting the first regular undergraduate course on mathematical statistics in Britain.

Pearson's success in the applied chair is illustrated by the growth of his department. In the 1870s, the average number of students of applied mathematics was nineteen; under Henrici in the 1880s it grew to forty-three. By the late 1890s, that number had swelled to seventy-seven, so large that by 1896, the department was employing one assistant professor and two demonstrators.¹¹³ To the former position, Pearson appointed George Udny Yule (1871-1951), a former student of his who would also acquire a high reputation for his work in mathematical statistics, particularly in the areas of regression and correlation, time-series and epidemiology. Appointed the college's Newmarch lecturer in statistics in 1902, Yule's lectures in this position formed the basis of his *Introduction to the Theory of Statistics* (1911), which became a standard undergraduate textbook for many years.

¹¹⁰ Ker, *op. cit.*, (10), 62.

¹¹¹ *University College, London. Calendar. Session 1894-95*, (London: Taylor and Francis, 1894), 60.

¹¹² *University College, London. Calendar. Session 1898-99*, (London: Taylor and Francis, 1898), 69.

¹¹³ Ker, *op. cit.*, (10), 60-62.

Another former student who was also to return as an assistant professor, this time in the pure department, was L. N. G. Filon. An undergraduate at the college between 1894 and 1898, Filon was one of the first students to return to the college to pursue postgraduate research, in which direction he was strongly influenced by both Hill and Pearson. After obtaining both the B.A. and M.A. degrees in London, he had entered King's College, Cambridge, as one of the earliest "advanced students"¹¹⁴ there. In 1902, a year after obtaining his Cambridge degree, he was awarded a D.Sc. by the University of London for three research-level dissertations.¹¹⁵ In 1903, shortly after the endowment of the Astor chair, he was appointed assistant professor of pure mathematics at the college, in which capacity he wrote *An Introduction to Projective Geometry* (1908), which was used by succeeding lecturers as recently as the 1950s.

By the turn of the century, mathematics at University College was very different from the subject as taught thirty-three years previously. Perhaps the most noticeable changes had occurred in the subjects included in the syllabus, especially in geometry, with the expulsion of Euclid and the introduction of modern techniques such as projective geometry and graphical statics. However, the mode of its teaching was also different, with the professor no longer being responsible for every lecture, but rather delegating certain duties to his assistant or assistants. Furthermore, the nature of the lectures themselves had also evolved to suit the changing requirements of the students, now no longer purely undergraduates. Indeed, the phenomenon of the postgraduate research student, of which scholars such as Filon and Yule are among the earliest examples, was to become increasingly common during the twentieth century.

The mathematics course and its teaching may have changed considerably since the days of De Morgan, but throughout, University College had remained the prime source of advanced mathematical tuition in London. However, the educational situation in London by 1900 was very different from that when De Morgan had commenced his teaching duties in 1828. Then, the college was almost unique in providing university-level mathematical teaching in the capital. However, as the nineteenth century progressed, it had been joined by a range of other institutions which, by the end of our period, could all claim to offer a similar standard of tuition in the subject. Therefore, to place the preceding chapters in their appropriate historical

¹¹⁴ Venn, *op. cit.*, (32), 2, 494.

¹¹⁵ The University of London Thesis Catalogue lists these as:-

- On certain diffraction fringes as applied to micrometric observations;
- On the elastic equilibrium of circular cylinders under certain practical systems of load;
- On the resistance to torsion of certain forms of shafting, with special reference to the effect of keyways.

context, as well as to compare the mathematical instruction of De Morgan and his successors at University College with that offered at contemporaneous institutions, a survey of these competitors now follows.

Chapter 7

Mathematics in the Metropolis, 1828-1900

7.1 Introduction

A discussion of any aspect of nineteenth-century London is necessarily complex. In common with its subject, it must cover a vast area, for the London of 1828 was very different, in both size and character, from the huge metropolis which had evolved by the turn of the century. For a consideration of mathematics in the capital at this time, it is therefore essential to limit our attention to some particular aspect of the topic in order to avoid producing an unduly prolonged, and possibly less informed, version of the present work. Therefore, to complement the material hitherto discussed in this thesis, the current chapter will provide an overview of higher mathematical education elsewhere in the capital during the same period. Consequently, this will not embrace related topics such as mathematics at school or elementary level, or, at the other end of the spectrum, research level mathematics. This chapter will concentrate solely on the teaching, at university level, of mathematics in London between the years 1828 and 1900, and the mathematicians who taught it.

In 1828, as Augustus De Morgan commenced his teaching career, London was served by very few institutions offering tuition in higher level mathematics. The first was the newly-established college in which he taught, then known as the London University. Distinctly radical for its time and viewed with deep misgivings by the Establishment of the day, its inauguration had prompted the foundation of the second institution for higher education in the capital. Disturbed by the secular nature of the "godless institution of Gower Street",¹ several leading political and religious figures established a rival body in 1829. To reflect its distinctly pro-Establishment credentials, it was named the King's College with the approval of the king, George IV. It opened on the Strand, in central London, in 1831, offering similar tuition to that of its rival but with the addition of compulsory lectures in theology. Moreover, to be eligible for membership of the college, it was necessary to conform to the thirty-nine articles of the Church of England - although anyone was permitted to attend lectures on payment of the requisite fee.

¹ Negley Harte and John North, *The World of UCL 1828-1990*, (London: University College London, 1991), 31.

It has been shown that, due to its nonconformist character, the London University was consistently denied a royal charter, resulting in its being unable to award anything higher than general certificates during its formative years. Yet despite its conservative nature and royal patronage, King's College was equally impotent in the matter of conferring degrees, its graduates becoming only Associates of King's College, or A.K.C. This antagonistic situation was at least partially resolved in 1836 with the Whig government's creation of the present University of London. As will be recalled from Chapter 3, this was founded purely for the purpose of examining students from the two London colleges and awarding degrees. This situation remained unaltered throughout the century; however, as will be seen, the number of teaching bodies affiliated to the University of London was to increase dramatically by the end of our period as was the character of the university itself.

The third and final institution offering instruction in university-level mathematics at the beginning of our period was of a very different character. Indeed, formally speaking, during the entire Victorian period, it lay outside London. However, its adjacency to the capital and the many institutional and personal links between it and the rest of London make it an important constituent of this study. This was the Royal Military Academy in Woolwich. Founded by George II in 1741, for nearly a century it had been "instructing the people of the Military branch of the Ordnance . . . [in] whatever may be necessary or useful to form good Officers of Artillery and perfect Engineers".² Subjects studied by the cadets included fortification and artillery, as well as drawing, chemistry, French, fencing and dancing. However, it was the study of mathematics and its applications which particularly dominated the course.

Unlike the students of mathematics at University or King's Colleges, the gentlemen cadets of Woolwich were not studying for degrees or academic qualifications; they were competing for commissions in either the Royal Artillery or the Engineering Corps of the British Army. Admissions procedures at the Military Academy were somewhat more stringent than at its academic counterparts. Entry was by examination between the ages of fourteen and seventeen, with candidates being required to be perfect in Euclid Book I and have a knowledge of algebra up to the solution of linear equations in two unknowns, in addition to other requirements in classics, French, history, geography, and drawing. However, as will be shown, neither the mathematics course offered by the professors nor the performance of the cadets matched the standard one would expect from such scrupulous requirements.

² Henry Donald Buchanan-Dunlop (ed.), *Records of the Royal Military Academy 1741-1892*, (Woolwich: F. J. Cattermole, [1895]), 2.

This, then, was the situation in London for university-level mathematics at the start of our period. Choice was indeed limited: either academic or military. The educational needs of upper and middle class young men were certainly well provided for, but as far as women or the working classes were concerned, the situation was highly unsatisfactory. The creation of the London Mechanics' Institute in 1823 (and similar bodies across the country thereafter) had provided the foundations of further education for artisans, but academically remained far inferior to the middle class colleges. For women, no higher educational body existed at all. But the Victorian period was to witness great changes, not least in the improvement of the range, choice, and availability of higher education to previously neglected sections of society. An excellent illustration of these changes is found in the development of higher mathematical instruction in the capital; and it is to a review of such tuition and the institutions concerned that we now proceed.

7.2 King's College

Throughout the nineteenth century, King's College remained the only major academic rival to University College in London. As far as mathematics was concerned, however, the overall calibre on the Strand was far more modest. King's first professor of mathematics, the Reverend Thomas Grainger Hall (1803-1881), had, in 1827, been a candidate for the chair at University College to which De Morgan was subsequently elected. Fifth wrangler in 1824 and fellow of Magdalene College, Cambridge,³ Hall was finally elected to the mathematics chair at King's in 1830, "which he continued modestly, faithfully and inconspicuously to occupy (rather than fill) for the next thirty-nine years".⁴

But Hall did not just teach mathematics. For the first few years of its existence, King's College was without a professor of history, which resulted in the amusing scenario of Hall teaching mathematics from Monday to Thursday and, on Friday, lecturing on history from Christophe Koch's *History of the Revolutions in Europe* (1826).⁵ As a result, in 1833 he was permitted to appoint a lecturer to assist in the teaching of mathematics. During the 1840s and early 1850s, Hall's classes bore notable fruit:

³ John A. Venn, *Alumni Cantabrigienses*, Part 2, (Cambridge: Cambridge University Press, 1940-1954), 3, 204.

⁴ Fossey J. C. Hearnshaw, *The Centenary History of King's College London 1828-1928*, (London: G. G. Harrap & Co., 1929), 89.

⁵ 1833-1834. *Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, (London: B. Fellowes, 1833), 14.

twenty-five of the wranglers between 1840 and 1844 had attended King's College, including one of the most distinguished senior wranglers, Arthur Cayley. The years 1843-1852 saw fifty-one King's alumni achieve wranglerships, and in 1853, all previous records were broken when no fewer than thirteen wranglers and nine senior optimaes were King's men.

During his long tenure, Hall wrote a number of mathematical textbooks, upon which much of his course was based. These included *A Treatise on Differential and Integral Calculus* (1834), *A Treatise on Plane and Spherical Trigonometry* (1836), *Elements of Algebra* (1840) and *Elements of Descriptive Geometry* (1841), although it is doubtful that he ever taught more than the rudiments of the last subject. By the mid-1850s, however, his interest in mathematics and its teaching had languished. He had been appointed a prebendary of St. Paul's Cathedral in 1845, a position he held until his death, and it seems that he became far more concerned with church matters than the mundane instruction of undergraduates which his staff, now consisting of two lecturers, were quite capable of undertaking. Indeed, by the time he resigned his chair in 1869, "he had long been apathetic and devoid of active interest in either his subject or his pupils".⁶

Table 1
King's College Professors 1830-1900

MATHEMATICS

1830-1869 :	Rev. Thomas Grainger Hall
1869-1882 :	Rev. William Henry Drew
1882-1903 :	William Henry Hoar Hudson

NATURAL PHILOSOPHY

1831-1844 :	Rev. Henry Moseley
1844-1854 :	Rev. Matthew O'Brien
1854-1860 :	Thomas Minchin Goodeve
1860-1865 :	James Clerk Maxwell
1865-1905 :	William Grylls Adams

⁶ Hearnshaw, *op. cit.*, (4), 305.

His colleague in the chair of natural philosophy was a more active mathematician. The Rev. Henry Moseley (1801-1872) had also been an unsuccessful contender for the University College chair in 1827. Following his rejection, he had served as canon of the village of West Monkton, Somerset, before being selected as professor of natural and experimental philosophy and astronomy at King's in 1831.⁷ Unfortunately, his working relationship with Hall did not proceed as amicably as either would have wished. Even before the college opened, disputes had begun over the demarcation of subjects. The five compulsory topics for undergraduate study were specified as religious instruction, classics, mathematics, English, and history.⁸ Since income was determined by the number of students, the professors of these subjects would be at a considerable financial advantage over those whose courses were merely optional. If we then compare Hall's mathematical syllabus to the course offered by De Morgan at University College, we may understand the source of contention:

- | | |
|--------------|--|
| FIRST YEAR: | <ul style="list-style-type: none"> i) Euclid, Books 1, 2, 3, 4, 6, 11 ii) Arithmetic and algebra iii) Plane Trigonometry iv) Elementary Differential & Integral Calculus |
| SECOND YEAR: | <ul style="list-style-type: none"> i) Elementary Mechanics ii) Theory of Equations iii) Differential and Integral Calculus iv) Newton's <i>Principia</i>, sections 1, 2, 3 v) Conic Sections |
| THIRD YEAR: | <ul style="list-style-type: none"> i) Geometry of three dimensions ii) Spherical trigonometry iii) Analytical mechanics iv) Hydrostatics, optics and astronomy v) Newton's <i>Principia</i>, sections 9 & 11 vi) Differential equations.⁹ |

Unlike the 'pure' course offered at University College at this time, the King's mathematical programme can be seen to contain material that could be designated as applied or 'mixed' mathematics. Thus a significant portion of Hall's syllabus infringed on what Moseley considered to be the domain of his natural philosophy (or applied mathematics) course. Moseley complained to the college council that not only was his course a minority option, but much of it was already being taught in compulsory

⁷ At his request, in 1834 experimental philosophy was given a separate chair, of which Charles Wheatstone was the first occupant.

⁸ 1834-1835. *Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, (London: B. Fellowes, 1834), 9.

⁹ *Calendar of King's College, London, for 1848-9*, (London: John W. Parker, 1848), 51-52.

lectures by the professor of mathematics, thus decreasing his potential class size.¹⁰ The council ruled in Hall's favour, but Moseley's situation was improved slightly in 1838 with the establishment of a course in civil engineering (the first in London), for whose students lectures in natural philosophy were vital.¹¹

To supplement his income, as well as provide a basis for his course, Moseley also published a number of works on the subjects with which he was engaged in teaching, most notably *A Treatise on Hydrostatics and Hydrodynamics* (1830), *Illustrations of Mechanics* (1839) and *The Mechanical Principles of Engineering and Architecture* (1843). Eventually, possibly lured by a higher (and more reliable) salary, he resigned his chair to become a school inspector.¹² He continued to write on applied mathematics, his best known work being a paper in the Royal Society's *Philosophical Transactions* of 1850, containing formulas by which the dynamical stability of war ships was calculated for many years.¹³

Moseley was succeeded in 1844 by the Rev. Matthew O'Brien (1814-1855), an Irishman and graduate of both Trinity College, Dublin, and Caius College, Cambridge (where he was third wrangler in 1838).¹⁴ Like his predecessor, O'Brien also had to supplement the somewhat unpredictable income derived from his college teaching; accordingly, in 1849, he was appointed lecturer on astronomy at the Royal Military Academy, a position he held in tandem with his King's professorship for the next five years. It was his promotion to the professorship of mathematics at Woolwich (see Section 7.4.1 below) that led to the resignation of his original post and the termination of his association with King's College in 1854.

His replacement in the chair of natural philosophy, Thomas Minchin Goodeve (1821-1902), is another figure whose name will recur in the teaching of mathematics in Victorian London. Ninth wrangler in 1843,¹⁵ his teaching career had begun three years later when he joined the mathematics department as one of Hall's assistant lecturers. He succeeded O'Brien not only at King's in 1854, but also the following year as lecturer on astronomy at Woolwich. He too carried out the duties of both

¹⁰ King's College London Archives: In-Correspondence, M6, Henry Moseley to Council, 8 Dec. [1831].

¹¹ 1838-1839. *Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, (London: B. Fellowes, 1838), 7-8.

¹² King's College London Archives: In-Correspondence, M34, Henry Moseley to the Rev. Dr. Jelf, 5 Jan. 1844.

¹³ Henry Moseley, On the Dynamical Stability and on the Oscillations of Floating Bodies, *Philosophical Transactions of the Royal Society*, **140** (1850), 609-643.

¹⁴ *D.N.B.*, **41**, 319.

¹⁵ Venn, *op. cit.*, (3), **3**, 82.

positions simultaneously for a number of years. Eventually, however, "like his predecessor [he] was lured to Woolwich by the superior emoluments which the government could offer"¹⁶ and left the college in 1860 to fill the newly-established professorship of mechanics at the Academy.

The college now acquired a man of outstanding scientific skill as its new professor. James Clerk Maxwell (1831-1879) was arguably the foremost British mathematical physicist of the nineteenth century. Best known for his research into electricity and magnetism, his first paper, 'On the Description of Oval Curves', had been communicated to the Royal Society of Edinburgh when he was just fifteen.¹⁷ Second wrangler in 1854 (when E. J. Routh had come first), Maxwell moved to London from Aberdeen, where between 1856 and 1860 he had held the professorship of natural philosophy at Marischal College.¹⁸ Yet, remarkable though his scientific credentials may have been, "as a teacher of raw youths, ... he did not prove to be a success. 'He was,' says one who knew him, 'a quiet and rather silent man, and it seems not unlikely that the students were too much for him' ".¹⁹

His inability to maintain order in his classes was exacerbated by additional shortcomings as a lecturer. Ivan Tolstoy, in his biography of Maxwell, explains:

The evidence is that, as a teacher, he had unusual difficulties. His delivery was poor. He could control neither the speed of his thought nor the flights of his mind. He tended to pursue sidelines - sudden inspirations, which took him in unpredictable directions. He made mistakes. As Horace Lamb, a later junior colleague at Cambridge, would put it "he had his full share of misfortunes at the blackboard". Very likely only the occasional, particularly brilliant student could follow his lectures. ... As a great scientist, an honest man, and a dutiful teacher he would dearly have liked to transfer his own mastery of these ingredients to his students; but his success at this remained at all times erratic.²⁰

Despite these deficiencies, it appears that Maxwell "was conscientious, meticulous and well-organized in the preparation of his lectures ... [taking] great care in selecting and ordering the material for his courses. Their conception and organization were modern in spirit, covering mechanics, optics, electricity and magnetism".²¹

¹⁶ Hearnshaw, *op. cit.*, (4), 247.

¹⁷ *D.N.B.*, **37**, 118-121.

¹⁸ Venn, *op. cit.*, (3), **4**, 371.

¹⁹ Hearnshaw, *op. cit.*, (4), 247.

²⁰ Ivan Tolstoy, *James Clerk Maxwell: A Biography*, (Edinburgh: Canongate, 1981), 100.

²¹ *ibid*, 99.

Nevertheless, in October 1863, William Grylls Adams (1836-1915), brother of the astronomer John Couch Adams, was appointed assistant lecturer in natural philosophy to relieve Maxwell's teaching burden. After a year of this arrangement, it is reported that there was "not enough going on, apart from noise, to give employment to two teachers; hence, early in 1865, it would appear, an intimation was conveyed to Clerk Maxwell that he should resign".²²

This anecdote comes from no less an authority than the 1929 *Centenary History of King's College London* by F. J. C. Hearnshaw. Subsequent research by Cyril Domb has successfully revealed the dubious origin of the account; a desire to return to Scotland and devote more time to research and writing provides a far more satisfactory explanation for Maxwell's departure than his being asked to leave by the college council.²³ Domb adds that Hearnshaw's belief that, by placidly accepting Maxwell's resignation, the College left him free to carry out the researches which made him world famous, is clearly inaccurate, since many of Maxwell's important papers were published before 1865. Whatever its motive, the resignation was tendered on 10 February 1865, the college council resolving "that in accepting Professor Maxwell's resignation they desire to convey to him their best thanks for the services which he has rendered to the college, and to express their high appreciation of his talents and attainments".²⁴

Adams, who, unlike Maxwell, was described by Hearnshaw as being "an excellent lecturer and strong disciplinarian",²⁵ was immediately appointed to the vacant professorship. Despite other reports that he was "unable to deal properly with the rowdy students" and had "been in the habit of 'lecturing' to one class by hanging up large sheets of canvas on which the lecture was written and pointing with a stick to line after line",²⁶ Adams remained in the post for forty years. His retirement in 1905 prompted a reorganisation of mathematical teaching similar to that which had taken place at University College in 1865. Natural philosophy was split into physics and applied mathematics: the former acquiring its own professorship, the latter coming under the jurisdiction of the professor of mathematics.

²² Hearnshaw, *op. cit.*, (4), 248.

²³ Cyril Domb, James Clerk Maxwell in London 1860-1865, *Notes and Records of the Royal Society*, **35** (1980), 67-103, pp.92-95.

²⁴ Hearnshaw, *op. cit.*, (4), 248.

²⁵ *ibid.*

²⁶ Domb, *op. cit.*, (23), 95.

To this chair, following Hall's retirement in 1869, the council had appointed the Rev. William Henry Drew (1827-1882). He had been eighth wrangler in 1849,²⁷ but apart from that and being the author of a moderately well-known *Geometrical Treatise on Conic Sections* (1857) he seems to have had little else to recommend him. Since he was at that time employed as assistant master at Blackheath Proprietary School, he was presumably selected more for his teaching skills than his mathematical originality. Thus, while no noticeable course changes were made, the mathematics department operated "with admirable efficiency"²⁸ during Drew's term in office.

On Drew's early death in 1882 the chair was filled, with equal vigour, by William Henry Hoar Hudson (1838-1915). A notable King's alumnus, Hudson had entered the college as a student in 1855, graduating as the senior mathematical scholar two years later. In 1861, he came out as third wrangler at Cambridge, becoming a fellow of St. John's College shortly afterwards and lecturing there from 1869.²⁹ In his new position he proved himself to be "a man of immense vivacity and energy",³⁰ though not, it would seem, of particular pedagogic originality. The same can also be said of his immediate successors in the chair following his retirement in 1903. In fact, for the first third of this century, King's continued in much the same spirit as before, offering no serious mathematical opposition to its Gower Street competitor.

It would appear, therefore, that in both pure and applied mathematics, tuition at King's throughout the nineteenth century was adequate though hardly innovative. With the obvious exception of Maxwell, King's was also noticeably bereft of first-rate mathematical researchers, especially in pure mathematics. The combined skill in research and teaching, evident in so many of the staff at University College (e.g., De Morgan, Clifford, Henrici, Pearson), was curiously absent from King's mathematical personnel, Maxwell's disappointing performance as a lecturer proving the rule. Indeed, one observes no mathematical professors of note in the Strand before the appointment of George Barker Jeffery in 1922, and it was not until the arrival of George Temple and John Greenlees Semple in the 1930s that the superiority of University College mathematics was significantly challenged by its old rival.³¹

²⁷ Venn, *op. cit.*, (3), 2, 339.

²⁸ Hearnshaw, *op. cit.*, (4), 305.

²⁹ Venn, *op. cit.*, (3), 3, 474-5.

³⁰ Hearnshaw, *op. cit.*, (4), 305.

³¹ Clive W. Kilmister, The Teaching of Mathematics in the University of London, *Bulletin of the London Mathematical Society*, 18 (1986), 321-337, p.322.

7.3 Mathematics for Women

The educational situation for London's women in 1828 was highly deficient, a fact which, despite the installation of a female monarch nine years later, remained unchanged throughout the following decade. King's College statutes denied membership to non-Anglican *males*, let alone women (Anglican or otherwise), while University College, notwithstanding its doctrinal liberality, also remained an exclusively male domain. Yet it was the staff of the apparently more conservative college on the Strand who were to be instrumental in the establishment of a college for London's women. Chief among them was Frederick Denison Maurice (1805-1872), a deeply committed Christian Socialist clergyman and professor of divinity at King's. Largely through his efforts, the first college in the country expressly for the education of women was founded in Harley Street. Queen's College, as it was called, opened in 1848 as a branch of the Governesses' Benevolent Institution. Maurice and several other professors from King's lectured in its opening months, including Hall in mathematics and O'Brien in natural philosophy.

The inclusion of such topics as mathematics and natural philosophy in the education of young women can be seen as a somewhat daring measure for the time. Mathematics was not then usually considered to be a high priority subject for girls from respectable and affluent families to study. Consequently, the founders of Queen's College felt obliged to justify its inclusion in the syllabus, Maurice drawing attention to the subject's inherent interest in addition to its utility. In his inaugural lecture, Professor Hall reassured his audience that although it had the potential "to unfit the mind for application to the purposes of life",³² mathematics at Queen's would not be studied to such an extent as to jeopardise the students' mental powers, concurring with Maurice's view that "our pupils are not likely to advance far in mathematics".³³ The principal benefit of studying the subject, said Hall, was the discipline it imposed on one's studies:

It may be a proud exercise of the intellect to read the language which Newton taught ... but our task, and your task, is a more humble one. We must teach, and you learn, the grammar of a science, which demands and will repay your attention; diligence and thoughtful patience are the chief requisites to obtain success: and these being given, a reward will certainly follow.³⁴

³² *Introductory Lectures Delivered at Queen's College, London*, (London: John W. Parker, 1849), 323.

³³ *ibid*, 16.

³⁴ *ibid*, 345.

Like its parent institution, Queen's College was operated on explicitly Anglican lines, a fact which soon led to the inauguration of a second women's college, on a nonconformist basis. The principal figure this time was Mrs. Elizabeth Jesser Reid, a widowed lady of property, whose dissenting background had acquainted her with many liberal educationalists of the day, including some of the professors at University College. With their support, and her money, Mrs. Reid bought a house in Bedford Square (at the southern end of Gower Street), "paid the rent and much of the expense during the first few years, and otherwise endowed the Institution".³⁵ It opened in 1849 as The Ladies' College, 47 Bedford Square, with many of its first professors being drawn from University College.

Among them was Augustus De Morgan, who served as the first professor of mathematics, giving "lectures or lessons on arithmetic and algebra for one year".³⁶ In fact, he had actually withdrawn before the college completed its first year. We are told in the history of Bedford College that "Professor De Morgan left at Easter (1850), on the ostensible ground of pressure of important work in other directions. Mrs. Reid herself sets it down to 'no remuneration' "³⁷ which is also highly plausible since his class numbered only seventeen ladies in the first term and eighteen in the second. Moreover, it would be pertinent to suggest that a man described as "an unfathomable fund of mathematics"³⁸ may well have felt his time wasted in lecturing to girls who only had a very elementary knowledge of arithmetic.

In these formative years of female higher education, most of the students were insufficiently trained to benefit from the teaching offered since many were surprisingly young, the age requirement being "twelve years and over".³⁹ However, the teenage girls and the few more mature ladies who attended the lectures in the early days of these two colleges were initiating a momentous development in higher education, although they were not yet in a position to come within the realm of the University of London. Instead, Queen's and Bedford Colleges operated more as finishing schools for young ladies, the limitations of their students' previous education ensuring that the level of tuition could never rival that of their male counterparts. Consequently, the professors of mathematics employed at both institutions were not required to be first-

³⁵ Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, & Co., 1882), 174.

³⁶ *ibid.*

³⁷ Margaret J. Tuke, *A History of Bedford College for Women 1849-1937*, (London: Oxford University Press, 1939), 65.

³⁸ Harriet Ann Jevons (ed.), *Letters and Journal of W. Stanley Jevons*, (London: Macmillan & Co., 1886), 150.

³⁹ A. Geoffrey Howson, *A History of Mathematics Education in England*, (Cambridge: Cambridge University Press, 1982), 172.

rate mathematicians and, at Queen's College at least, that non-requirement was certainly met.

Like De Morgan at Bedford, Queen's first mathematics professor, Thomas Hall, also resigned his post within a year of the college's opening. His place was taken by one of his mathematical assistants from the Strand. Thomas Astley Cock (1812-1885) was an obscure low wrangler who had been giving lectures on mathematics at King's since 1840, and was to continue doing so for another thirty-nine years.⁴⁰ Yet even his retirement in 1879 could not remove him from the position in Harley Street, where he insisted on remaining as long as his health would hold. Only his death in 1885 provided Queen's College with a new professor of mathematics, his successor being the vigorous William Henry Hoar Hudson, who lectured there until 1905.⁴¹

Table 2
Bedford College Professors of Mathematics 1849-1900

1849-1850	:	Augustus De Morgan
1850	:	Rev. James Booth
1850-1851	:	Francis William Newman
1851-1853	:	Rev. William Cooke
1853-1856	:	Rev. Henry J. Hose
1856-1857	:	Rev. Walter Mitchell
1858-1865	:	Richard Holt Hutton
1865-1869	:	Jonas Ashton
1869-1870	:	Olaus Henrici
1870-1907	:	Percy J. Harding

At Bedford College, the majority of the mathematics professors who succeeded De Morgan were better known for their skills in other areas. For example, Francis William Newman (1805-1897) was a brilliant but eccentric professor of Latin at University College. Condemning urban life "because he disapproved (in principle) of drains, he said of himself that to be in conflict with current opinion was to be in his

⁴⁰ Venn, *op. cit.*, (3), 2, 80.
⁴¹ Despite its professors being male, Queen's College also had women on its staff, one of the most notable being Mary Everest Boole (1832-1916), wife of the mathematician George Boole, who taught there for some time after her husband's death in 1864.

element".⁴² He resigned after only a year in the chair over a question of religious discord. Richard Holt Hutton, previously mentioned in Chapter 5, had been an outstanding pupil of De Morgan at University College in the 1840s. His time at Bedford College (concurrent with his co-editorship of *The National Review* with Walter Bagehot) was notable for his publication of *The Relative Value of Studies and Accomplishments in the Education of Women* (1862).

For twenty years, the two ladies' colleges remained the sole teaching establishments for young women in London, until they were supplemented by the formation of the London Ladies Educational Association. In 1868, this body began to organise lectures in the vicinity of University College, though outside its premises. During the academic session 1871-72, gradual moves towards mixed classes were made in the college, with the first integrated classes being given in art and political economy. Other professors soon followed suit; for instance, in 1876 Henrici admitted ladies to his higher senior mathematics class. Finally, in 1878 University College became the country's first coeducational institution with 288 women being admitted as undergraduates in its Faculties of Arts, Laws and Science. Simultaneously with this, the University of London opened its examinations to women, who could now compete for degrees with men on an equal basis.

The integration of higher education in the capital did not, as one might perhaps expect, signal the end of the ladies' colleges or even a decline in the number of students. On the contrary, due to increased demand, in 1879 a higher mathematics class was introduced at Bedford College.⁴³ This also undoubtedly reflects the increased proficiency of its students: now that women could be examined equally with men, it was reasonable for them to expect that their tuition should reach the same standard. However, the same attitude did not, it would seem, prevail at London's original women's college: "The opportunities offered by the University's full recognition of women in 1878 were not taken by Queen's College, which became what it remains, a public school for girls."⁴⁴

It was not long before women began to graduate with distinction in mathematics from the University of London. Sophie Bryant, later headmistress of the North London Collegiate School and one of the first women members of the University Senate, was one of the first women to take the BSc examination in 1881. She was also "the first

⁴² Kilmister, *op. cit.*, (31), 324.

⁴³ *ibid.*

⁴⁴ Negley Harte, *The University of London 1836-1986*, (London: Athlone Press, 1986), 131.

woman to attain a doctorate when she took a DSc in 1884".⁴⁵ Other early female graduates were Philippa G. Fawcett, an alumna of both Bedford and University Colleges, who gained the distinction of being placed above the senior wrangler in the Tripos of 1890 (although, of course, she could not actually *graduate* from Cambridge), and Alice Lee, later to become a lecturer in physics at Bedford College.⁴⁶

The 1880s also saw the opening of three new ladies' colleges in the vicinity of the rapidly expanding capital. In 1882, The College for Ladies at Westfield was founded in Hampstead,⁴⁷ to be followed four years later by the opening of Royal Holloway College in Egham, Surrey.⁴⁸ King's College opened a Ladies' Department in 1885 - its location in Kensington rendering it a distinct entity from its parent college and ensuring continued separation of male and female students. It was finally incorporated in the University of London in 1910 as King's College for Women.⁴⁹ Thus we see that by 1900, the situation for women's higher education in the capital was beyond any comparison with that of seventy-two years earlier. Not only was university-level instruction in mathematics now available to women, it was almost as accessible to them as it was to men. One's ability to graduate was no longer contingent on one's gender - a very different situation to that in military mathematics, to which we now turn.

7.4 Military Mathematics

7.4.1 The Royal Military Academy, Woolwich

The British Army excluded women from entry into any of its branches throughout the nineteenth century. This policy was followed, too, at the prestigious Royal Military Academy in Woolwich. The reputation of this establishment in the mathematical world had been swelled in the first century of its existence by the distinguished professors that its generous salaries attracted, notably Thomas Simpson (1710-1761) and Charles Hutton (1737-1823). It was through the published works of the latter and other masters, such as Peter Barlow (1776-1862) (who contributed a number of excellent scientific articles to the *Encyclopædia Metropolitana* in the 1820s), that

⁴⁵ *ibid*, 128.

⁴⁶ William P. Ker, ed., *Notes and Materials for the History of University College, London. Faculties of Arts and Science*, (London: H. K. Lewis, 1898), 57, 63.

⁴⁷ Kilmister, *op. cit.*, (31), 332.

⁴⁸ S. Gordon Wilson, *The University of London and Its Colleges*, (London: University Tutorial Press, 1923), 61.

⁴⁹ *ibid*, 55-56; Harte, *op. cit.*, (44), 134.

British scholars became acquainted with recent mathematical and scientific developments on the continent.

This was partly for practical reasons, as Niccolò Guicciardini points out: "The practical needs of military engineering demanded sophisticated scientific knowledge: this partially explains why the Woolwich masters were so interested in contemporary continental works."⁵⁰ However, he goes on to say that although "with their textbooks and essays they greatly contributed to improving the knowledge of continental science in Britain, ... [a]s teachers they could not introduce any sophisticated innovations into the curriculum for the 'raw and inexperienced' cadets".⁵¹ Thus, favourably disposed as Hutton may have been to the progressive new European methods, he was "unable to use it in research and, in reality, never even attempted to teach it in written works".⁵² Consequently, his *Course of Mathematics*, upon which the Woolwich mathematical programme had been based since 1798, still employed the Newtonian fluxional calculus in preference to the more recent Lagrangian methods of which he was well aware.

In the three decades that elapsed between its publication and the start of our period, the *Course* went through many editions and revisions, yet Royal Military Academy cadets of the 1828 intake were still following a largely unchanged programme. This was despite further developments in the subject of the calculus such as the adoption of Leibnizian notation in Cambridge by the 1820s and the publication of new analytic methods by Cauchy at the École Polytechnique (in theory, France's equivalent to Woolwich, although in reality far superior). One would have expected the mathematical course at the country's foremost military college to have at least acknowledged recent progress in the subject, even given that the mathematics required by Woolwich cadets was of a different nature to that employed by those with purely academic needs. Indeed, when it is recalled that, at both of the Academy's scholastic London counterparts, differential and integral calculus was taught to a substantially high level, one can only view the content of the Woolwich mathematical course of 1828 as embarrassingly behind the times.

1. Arithmetic
2. Logarithms
3. Geometry (Euclid 1-4)
4. Algebra, to cubic equations

⁵⁰ Niccolò Guicciardini, *The Development of Newtonian Calculus in Britain 1700-1800*, (Cambridge: Cambridge University Press, 1989), 109.

⁵¹ *ibid*, 108.

⁵² *ibid*, 112.

5. Trigonometry, with heights and distances
6. Mensuration, with surveying and measuring
7. Conic sections
8. Mechanics
9. Fluxions
10. Hydrostatics and Hydraulics
11. Pneumatics, using air-pumps, syringes,
thermometer and barometer
12. Resistance of fluids
13. Gunnery.⁵³

This contrasts considerably with the course offered at the École Polytechnique at this time. There, under the guidance of such figures as Chasles, Liouville, Sturm, and Poisson, the syllabus was far more up to date, including subjects such as analysis, descriptive geometry, and geodesy.⁵⁴ By comparison the Woolwich course seems obsolescent and elementary. Moreover, says Guicciardini, "we suspect that even the very elementary level required was not reached: from the *Records of the Royal Military Academy*,...,one gets the strong impression that the discipline of both the masters and the cadets was not exemplary".⁵⁵

Table 3
Professors of Mathematics
at the Royal Military Academy, Woolwich

1821	:	Olinthus Gilbert Gregory
1838	:	Samuel Hunter Christie
1854	:	Rev. Matthew O'Brien
1855	:	James Joseph Sylvester
1870	:	Morgan William Crofton
1884	:	Harry Hart

Professor of mathematics at the Royal Military Academy in 1828 was Olinthus Gilbert Gregory (1774-1841). A protégé of Hutton, Gregory had been appointed a master at Woolwich in 1803. There he had edited the well known *Gentleman's Diary* until 1819 and since that time had been the editor of its sister journal, the *Ladies' Diary*. Strictly speaking more an engineer than a mathematician, Gregory made perhaps his most

⁵³ Buchanan-Dunlop, *op. cit.*, (2), 33.

⁵⁴ Ivor Grattan-Guinness, *Convolution in French Mathematics, 1800-1840*, (Basel: Birkhäuser Verlag, 1990), 1261-1263, 1362-1367.

⁵⁵ Guicciardini, *op. cit.*, (50), 110.

noteworthy contributions to science in the form of his *Treatise of Mechanics* (1806) and his experiments to determine the speed of sound in 1823.⁵⁶ He was also one of the original sponsors of the London University, serving on its first council in the late 1820s. Appointed professor of mathematics at Woolwich in 1821, Gregory continued his patron's efforts at spreading knowledge of continental developments in mathematics and physics by means of his published works, which included *Mathematics for Practical Men* (1825) and *Hints to the Teachers of Mathematics* (1840).

A possible reason why the course taught to cadets at Woolwich remained so little changed was that, especially in matters concerning the calculus, Gregory was far more conservative than Hutton, greatly preferring the Newtonian version to its continental competitors. Following Hutton's death, Gregory edited a number of editions of the *Course*, of which the eleventh - published in 1837 - is particularly interesting since it contains the fluxional approach in its main text as well as a translation of Lubbe's *Lehrbuch des höhern Kalkuls* in an appendix. In spite of this desire to increase British awareness of the methods and results of the continental school, Gregory made it quite clear where his loyalties lay, the 1837 edition of the *Course* containing the following declaration: "The Editor has long been of the opinion that, in point of intellectual conviction and certainty, the fluxional calculus is decidedly superior to the differential and integral calculus."⁵⁷

The chances of reforming the Woolwich course were substantially increased with Gregory's retirement in 1838. The Academy's governing body selected as his successor the first Cambridge man to hold the position, Samuel Hunter Christie (1784-1865). Primarily a mathematical physicist, Christie was also Secretary of the Royal Society to whose *Philosophical Transactions* he contributed fourteen papers, mainly on magnetism.⁵⁸ Second wrangler in 1805 and a mathematics master at Woolwich since 1806, Christie was keenly aware of the need to reform all academic aspects of the Academy. However, before his promotion to the professorship, he had been given little opportunity to put his ideas into practice, his only achievement in this area being the introduction of a new system of competitive examinations in 1812.

One of Christie's first decisions as professor was to abandon Hutton's *Course* as the foundation of the Woolwich curriculum. However, this could not be done overnight; a

⁵⁶ *D.N.B.*, 23, 103.

⁵⁷ Charles Hutton, *A Course of Mathematics*, 11th edition, (ed. Olinthus Gregory), vol. 2, (London: Longman, Rees & Co., 1837), 203, note.

⁵⁸ *D.N.B.*, 10, 284-285.

new book would have to be written to replace it, and Christie devoted much of his first few years as professor to its preparation. The new course was finally ready for publication in the mid-1840s: Christie's *Elementary Course of Mathematics for the Use of the Royal Military Academy, and for Students in General* was published, in two volumes, in 1845 and 1847. With its inauguration, Hutton's textbook, used exclusively at the Academy for nearly half a century, was finally discarded. The new mathematics course now comprised the following components:

1. Algebra, inc. the binomial theorem, logarithms and infinite series
2. Geometry: Euclid Bks 1-4, 6, 11(part), and 12 (briefly).
3. Application of algebra to geometry
4. Trigonometry with heights and distances
5. Conic sections
6. Elements of differential calculus (i.e. max/min and tangent problems)
7. Elements of integral calculus (i.e. areas and lengths of curves)
8. Mechanics: from Whewell's *Elementary Treatise*.⁵⁹

Although an attempt to remedy the weaknesses inherent in Hutton's syllabus by introducing a programme more appropriate to the capabilities of the cadets, the new course still had considerable flaws. True, the fluxional calculus had at last been banished, but in its place were only the elements of differential and integral calculus with no problems more taxing than finding maxima, minima, or the areas under curves. Due no doubt to the shortcomings both of masters and cadets, it was apologetically noted that "at present this subject cannot be much dwelt on".⁶⁰ Even more extraordinary, however, is the virtual omission of applied mathematics, with the instruction in elementary mechanics proceeding no further than motions of projectiles in vacuo!

If the notion of a prospective artillery officer or engineer taking up his commission with such a trifling mathematical training seems absurd today, it was considered scandalous in certain contemporary quarters. An article in the *London Review* of the mid-1840s, ostensibly a (negative) critique of Christie's recently published course, sheds light on the desultory state of mathematical study at the Academy during this period. The author of the account described a chance meeting with two young and newly-qualified engineer officers en route to a survey. It quickly transpired that these men, when questioned, were both wholly unacquainted with the instruments they were supposed to be using and totally ignorant of the mathematics involved. They professed once to have been "up to *grinding equations*, but had almost forgotten all

⁵⁹ Buchanan-Dunlop, *op. cit.*, (2), 102.

⁶⁰ *ibid.*

about it, - it was such a bore".⁶¹ And these Woolwich graduates were supposedly the intellectual elite of the Royal Engineers!

Seeking elucidation as to exactly what scientific acquirements were bestowed by a course of study at Woolwich, the review's author questioned an anonymous "gentleman of the Royal Military Academy", who replied: "I would gladly tell you if I knew;... it is, however, such a quantity that though the maximum is not large, the minimum is very small. ... and only last evening a field-officer of the Royal Artillery told me that he never found the slightest use for his mathematics during his whole life. This officer, too, holds a post ... that would require mathematics, if any post could".⁶²

Christie's new course was soon deemed far too elementary and quickly rejected in favour of a new one, drawn up by three mathematical masters at the Academy, Stephen Fenwick, William Rutherford, and Thomas Stephens Davies, and finally published, in three volumes, between 1850 and 1852. Christie himself retired in 1854 and the professorship was duly advertised for competition. Although the names of most of the candidates are now lost, we do know the two principal contenders. Both were eminent mathematics teachers who have previously come to our attention in this thesis as professors of natural philosophy at King's and University Colleges, respectively: the Rev. Matthew O'Brien and James Joseph Sylvester.

All had not gone well for Sylvester in Virginia,⁶³ and he was back in England far sooner than he had anticipated. Being unable to find a suitable academic post on his return, he had been working for the last ten years as an actuary in London while still continuing his mathematical research. Barred by his religion from seeking employment at Oxford, Cambridge, or King's in London, and with De Morgan and Potter firmly ensconced at University College, Sylvester correctly saw the vacancy of the Woolwich professorship as a vital opportunity for him to re-enter the academic world, since the Academy imposed no religious restrictions on its staff or cadets. Yet in his bid for the vacant chair he was, initially at least, unsuccessful.

The Rev. O'Brien, in terms of mathematical skill and originality, was, to the twentieth century observer, the less accomplished of the two men. However, this was not the only criterion (if indeed it counted for anything): he had been working at the Academy

⁶¹ Woolwich Royal Military Academy and its Mathematics, *Wade's London Review*, (9) (June 1845), 639-60, p.640.

⁶² *ibid*, 644.

⁶³ Lewis S. Feuer, America's First Jewish Professor: James Joseph Sylvester at the University of Virginia, *American Jewish Archives*, 36 (1984), 151-201.

since 1849, lecturing on astronomy, thus having not only more recent teaching experience than his rival but also, one would assume, more influential connections within the establishment itself. Whatever the reasons, he was awarded the professorship in August 1854. However, at this point, fate intervened. Within months of his election, O'Brien was dead, and the chair again fell vacant. This time, armed with references from such mathematical luminaries as Hamilton, Kelland, Poncelet, Chasles, Salmon, Hermite, and Bertrand, not to mention the considerable influence of Lord Brougham, Sylvester was finally appointed professor of mathematics on 16 September 1855.⁶⁴

Unfortunately, and not for the first time in his career, Sylvester found his new job to be an intellectual disappointment, involving as it did the instruction of, what was for him, trivial mathematics to engineering students who deeply resented the amount of mathematics they were required to study. As with his former teaching posts, therefore, Sylvester's term as professor of mathematics did not improve his already erratic teaching skills. Indeed, his reputation among the gentlemen cadets as an irritable and absent-minded eccentric was well earned if the following anecdote is to be believed: "...on one occasion he suddenly looked up from a paper in the hall of study and demanded of the corporal on duty, 'What year is it?' An explosion of laughter in the room led to a 'scene', and the subsequent infliction of many punishments upon the cadets".⁶⁵

Sylvester's fiery temperament also resulted in his clashing at least once with the military authorities over his teaching load, although, given his excitable nature and dislike of conformity and structure, this is hardly surprising. Yet, despite these occasional wrangles and his general dissatisfaction with the standard of mathematics he was obliged to teach, he stayed on as professor of mathematics for fifteen years. Indeed, he was quite unprepared for the events which led to his premature departure from Woolwich in 1870, when changes in Academy regulations decreed that all members of staff over the age of fifty-five had to retire. The consequence was Sylvester's enforced early retirement from his chair and the end of his teaching career in London (although this was far from the end of Sylvester's involvement in higher mathematical education).⁶⁶

⁶⁴ University College London Archives: Brougham Correspondence, No. 20,240, James Joseph Sylvester to Lord Brougham, 16 Sept. 1855.

⁶⁵ Percy A. MacMahon, Obituary Notice of James Joseph Sylvester, *Proceedings of the Royal Society*, **63** (1898), ix-xxv, p.xviii.

⁶⁶ See Karen H. Parshall & David E. Rowe, *The Emergence of the American Mathematical Research Community 1876-1900: J. J. Sylvester, Felix Klein, and E. H. Moore*, (Providence: AMS, and London: LMS, 1994), 72-146.

Sylvester's term of office had seen several new developments take place in the administration of the Academy designed to increase its efficiency and the standard of education therein. In 1855, the Board of Ordnance, under whose direction the Academy had previously been administered, came under the control of the War Office. Before that time, admission to the Academy could be obtained only by nomination from the Master-General of the Ordnance, followed by an entrance examination. The new management immediately introduced a system of open competitive examinations, the first such test being held in August 1855.

The chief examiner was Henry Moseley, erstwhile professor of natural philosophy at King's College. His report reveals that the level of the examination was hardly severe. He wrote: "Only 31 out of 151 candidates afforded evidence of mathematical knowledge to which the designation 'moderate' was applied by the examiners."⁶⁷ It should be noted that their definition of moderate was the "power to work an easy sum in arithmetic, demonstrate a proposition in the first book of Euclid, and solve a simple equation".⁶⁸ June 1865 saw the first examinations take place under completely independent examiners, "the Cadets coming out in much the same order as when examined by the Academy Professors, but with lower marks".⁶⁹ Yet this new system was far from perfect, as witnessed by a case in June 1869 when a cadet "who sent in blank papers and wrote no fair notes was allotted 120 marks in Practical Mechanics".⁷⁰

In 1828, subjects of study at the Academy, in addition to mathematics, were fortification, artillery, drawing, chemistry, French, fencing, and dancing. Between 1840 and 1860, the complete programme consisted of artillery, fortification, bridging, history, geography, landscape drawing, French, German, and mathematics with natural and experimental philosophy. In 1860, history and geography were dropped from the course and a professor of mechanics appointed. This was Thomas Minchin Goodeve, who resigned his professorship of natural philosophy at King's College to take the position - an unwise move since, in the same series of alterations which resulted in Sylvester's removal, his post was abolished in 1869 and combined with the professorship of mathematics the following year.

⁶⁷ Buchanan-Dunlop, *op. cit.*, (2), 120.

⁶⁸ *ibid.*

⁶⁹ *ibid.*, 128.

⁷⁰ *ibid.*, 129.

The first professor of mathematics and mechanics at Woolwich was the applied mathematician, Morgan William Crofton (1826-1915). Educated at Trinity College, Dublin, he had taken his B.A. in 1848 with the highest mathematical honours before serving as professor of natural philosophy at the newly-founded Queen's College, Galway, from 1849 to 1852.⁷¹ Since 1864 he had been teaching mathematics at Woolwich, where he was appointed on the recommendation of Sylvester. It was also due to his predecessor in the professorship that Crofton was able to publish some of his work on probability in the Royal Society's *Philosophical Transactions* of 1868 and 1870. He also contributed frequent papers to the newly-formed London Mathematical Society.

Both in his personality and his teaching, Crofton proved to be quite a contrast to the ebullient Sylvester, being "a man of reflective and retiring disposition".⁷² We are told that his method of teaching was the antithesis of Sylvester's, his mode of instruction being "terse and lucid"⁷³ and his mechanics relying on a "direct geometrical presentation".⁷⁴ This method was a great improvement on the efforts of his predecessor and far more appropriate to the needs of trainee engineers or artillery officers, "who require to have command of the ideas of the subject but may be distracted by analytical processes".⁷⁵ It seems to have been successful too, both militarily and mathematically, since at least two of Crofton's students went on to achieve fame: Lord Kitchener in the army, and Major Percy Alexander MacMahon in algebra. During his time at Woolwich, Crofton also wrote two short books for the use of the cadets, one of which, on applied mechanics, was widely used, at the Academy and elsewhere, for many years.

Crofton retired in 1884, to be succeeded by Harry Hart (1848-1920), fourth wrangler of 1871 and a mathematical instructor at Woolwich since 1873.⁷⁶ The principal event of his period as professor was the unveiling of a new mathematical syllabus in 1892. This course, divided into four classes and designed to take two years in total, built on alterations already initiated by Crofton:

4TH : i) Algebra, to the binomial theorem (using Hall & Knight's *Higher*
(Lowest) *Algebra*)

⁷¹ Joseph Larmor, Obituary Notice of Morgan William Crofton, *Proceedings of the London Mathematical Society*, (2) 14 (1915), xxix-xxx, p.xxix.

⁷² *ibid.*

⁷³ *ibid*, xxx.

⁷⁴ *ibid.*

⁷⁵ *ibid.*

⁷⁶ Venn, *op. cit.*, (3), 3, 268.

- ii) Trigonometry and Mensuration (using Todhunter's *Trigonometry* and Brabant's *Mensuration*)
 - iii) Analytical geometry (using Smith's *Conic Sections*)
 - iv) Mechanics (including Graphical Statics)
- 3RD :
- i) Analytical geometry (repetition of 4th Class course)
 - ii) Mechanics (repetition of 4th Class course)
 - iii) Applied mechanics (using Crofton's *Applied Mechanics*)
 - iv) Hydrostatics (using Besant's *Hydrostatics*)
- 2ND :
- i) Geometry (using Smith's *Conic Sections*)
 - ii) Spherical Trigonometry (using Goodwin's *Treatise*)
 - iii) Differential and integral calculus (using Greenhill's *Treatise*, especially re: applications to statics and dynamics)
- 1ST :
- (Highest)
- i) Statics and dynamics
 - ii) Hydrostatics
 - iii) Mechanism (using Goodeve's *Elements of Mechanism*)
 - including: a) conversion of circular into reciprocating motion
 - b) parallel motion
 - c) the use of wheels in trains
 - d) the steam engine.⁷⁷

Now, at last, the Academy had a mathematics course comparable to its continental rivals; the most noticeable feature of the new syllabus being the prevalence of applied mathematical subjects, indispensable to an apprentice engineer. Statics, dynamics, hydrostatics, and mechanisms were all taught to a considerable level, although the subject of hydrodynamics was curiously omitted for some reason. Another interesting characteristic is the shift from a primarily analytical to a more graphical and geometrically-inclined course (note the inclusion of graphical statics), perhaps influenced by a similar inclination at University College. Furthermore, a survey of the textbooks used leaves us in no doubt that the standard to which the Woolwich course of 1892 aspired was considerably higher than that of a few years before.

Comparison with its counterpart at the start of our period is instructive. Mathematics at Woolwich in 1828 had been old-fashioned and irrelevant to the needs of most of the cadets. By the end of the Victorian era, the course had changed almost beyond recognition both in the level of acquirement and applicability to the objectives of the institution. This was a clear rejection of the sloppy methods and over-simplification which had largely dominated instruction in mathematics at Woolwich for much of the nineteenth century. Hart's syllabus was the most progressive the Academy had implemented to date, consolidating the improvements begun by his predecessor. While

⁷⁷ Buchanan-Dunlop, *op. cit.*, (2), 135-136.

there was certainly still room for improvement, both in terms of content and quality of tuition, it was with this new curriculum that the Royal Military Academy entered the twentieth century.

7.4.2 The Royal Naval College, Greenwich

The British Army was not alone in teaching mathematics to its cadets; the subject was also an important ingredient in the curriculum of an establishment run by the Royal Navy, which began to rank as a London institution during the second half of our period. Founded as the Royal Naval Academy at Portsmouth in 1722, "for instructing young gentlemen in the sciences useful for navigation",⁷⁸ it served as a naval counterpart to Woolwich. The age of its cadets and the standard of their instruction were also, it appears, equally low. However, reforms had been underway since 1806 (when the school was renamed the Royal Naval College) which reduced its resemblance to the Woolwich Academy. Since 1829 it had also been training some commissioned officers and, most significantly, from 1839, had been an institution for adult education. In 1873, the College transferred from Portsmouth to Greenwich, reopening that autumn with Thomas Archer Hirst as its first director of studies and upwards of 200 students.⁷⁹

The most distinguished holder of the professorship of mathematics at the College in this period was William Burnside (1852-1927). He had been second wrangler in 1875 (jointly with George Chrystal) and since then had been teaching mathematics at Pembroke College in Cambridge. He was appointed to the professorship at the Naval College in 1885, where he was to remain until his retirement in 1919. Burnside is best remembered today for his work in group theory, in particular for *The Theory of Groups* (1897) which was a standard work for many years. However, his mathematical research ranged over an extensive area: he wrote over 150 papers on topics including automorphic functions, probability theory, complex analysis, and hydrodynamics. He was awarded the De Morgan Medal by the London Mathematical Society (of which he was President, 1906-1908) in 1899 - some indication of his mathematical stature at the time.

As professor of mathematics at Greenwich, Burnside was engaged in the teaching of three main topics: ballistics for gunnery and torpedo officers; mechanics and heat, for engineer officers; and dynamics, for naval constructors, where his "special mastery of

⁷⁸ Charles Hutton, *A Philosophical and Mathematical Dictionary*, vol. 1, (London: F. C. & J. Rivington, 1815), 16.

⁷⁹ William H. Brock and Roy M. MacLeod (eds.), *Natural Knowledge in Social Context: The Journal of Thomas Archer Hirst, F.R.S.*, (London: Mansell, 1980), 1984.

kinematics, kinetics and hydrodynamics proved invaluable".⁸⁰ But, like any good teacher of mathematics, his success did not rest solely upon his mathematical expertise. In his obituary of Burnside, the mathematician Andrew Forsyth wrote: "Records and remembrance declare that he was a fine and stimulating teacher, patient with students in their difficulties and their questions - although elsewhere, as in discussions with equals, his manner could have a directness that, to some, might appear abrupt."⁸¹

Thus, in 1900, London was twice as well served for instruction in higher-level mathematics for military use as it had been in 1828. This does not just refer to the number of such institutions. At the start of our period, neither the Military Academy nor the Naval College, irrespective of their locations, could be accurately described as university-level teaching establishments. At Woolwich in particular, neither the course offered nor the tuition given were comparable to their scholastic counterparts. Yet by the turn of the century, we see in the teaching of Burnside at Greenwich and Hart at Woolwich, consideration of topics which would not have been out of place in the advanced mathematical courses of any contemporaneous high-level academic institution. More importantly, the move towards applied mathematics at both schools reflects the growing awareness of the need for instruction in the utilisation of mathematics. This realisation was not unique to the military, as our next section reveals.

7.5 Technical Education

7.5.1 Background

By the mid-nineteenth century, British industry was fully aware of the need for a thorough technical education of the working population. The Great Exhibition of 1851, while certainly providing a showcase for Britain's impressive industrial prowess, had highlighted growing competition from new rivals such as Germany and the United States, where technical education was of major importance. Germany already had several Technische Hochschulen in cities such as Munich, Hanover, Stuttgart and, most famously, Charlottenburg, Berlin. In America, the Massachusetts Institute of Technology was opened in 1865. Other European countries were also amply equipped with technical institutions (e.g., the Federal Technische Hochschule of Zürich and the École Centrale des Arts et Manufactures in Paris). It was quickly realised that the

⁸⁰ Andrew Russell Forsyth, Obituary Notice of William Burnside, *Journal of the London Mathematical Society*, **3** (1928), 64-80, p.66.

⁸¹ *ibid.*

technical deficiency in the training of British artisans, if not remedied, would soon result in Britain losing her place as the world's foremost industrial power.

A start had been made earlier in the century by George Birkbeck (1776-1841), who, with other educational reformers (many of whom were later to play a part in the founding of London University), established the London Mechanics' Institute in 1823.⁸² Birkbeck and his associates had recognised early on that Britain, "though the first manufacturing country in the world, is singularly deficient in schools for instructing the people in the Mechanical Arts".⁸³ The new Mechanics' Institute was designed to redress this state of affairs, offering tuition in the physical sciences to working men or, in the words of its founders, "giving education to students in the principles of the Arts they practise, and in the various branches of Science and useful knowledge".⁸⁴ The lectures were certainly popular, prompting the inauguration of similar mechanics' institutes across the country until, by 1850, there were 600 Literary and Mechanics' Institutes nationwide. However, it quickly transpired that these institutes catered more to the lower middle classes than the workman, providing more in the way of general elementary education and social facilities than vocational training for the artisan. In any case, those for whom the tuition was originally intended found the technicalities too hard and the fees too high.

7.5.2 The Royal College of Science

The first moves towards constituting a thorough technical education at university level began around the time of the Great Exhibition. In 1845, the Royal College of Chemistry was founded in South Kensington. This was followed six years later by the establishment of the Government School of Mines and of Science Applied to the Arts. In 1853, on the creation of the Science and Art Department of the Board of Trade, the two schools were incorporated together. Although administered jointly, they remained distinct entities, the latter being renamed the Royal School of Mines ten years later. The next change occurred in 1881, when the schools moved to Exhibition Road in South Kensington and reopened as the Normal School of Science and Royal School of Mines, with Thomas Huxley (1825-1895) as the first Dean. The former school's title soon proved unpopular and was changed in 1890 to the Royal College of Science.

⁸² This was renamed the Birkbeck Literary and Scientific Institution in 1866, and finally Birkbeck College in 1907.

⁸³ Cecil Delisle Burns, *A Short History of Birkbeck College*, (London: University of London Press, 1924), 23.

⁸⁴ Wilson, *op. cit.*, (48), 75.

The College was "primarily intended for the instruction of teachers and of students of the industrial classes selected by competition in the examinations of the Board of Education",⁸⁵ although other students were admitted subject to space. The education provided in the College of Science was of a general scientific nature (physics, chemistry, and biology), whereas at the School of Mines, instruction was more specialised (mining, metallurgy, and geology). The intention of both bodies to provide a high standard of instruction is reflected by the professors they appointed to teach, most notably the professors of physics at the College of Science. The first such professor was George Stokes, supplementing his income as Lucasian Professor at Cambridge by lecturing part-time at the college between 1853 and 1859, to be followed by John Tyndall for the next ten years.

Tyndall's successor was Frederick Guthrie (1833-1886), younger brother of Francis Guthrie and ex-student of Augustus De Morgan (recall Section 5.1.1). Following his departure from University College, Guthrie had moved to Germany where he studied chemistry under Bunsen at Heidelberg, later receiving his Ph.D. from Marburg. From 1861 to 1867 he was professor of chemistry and physics at the Royal College of Mauritius, becoming professor of physics at the then Normal School of Science in 1869. He remained there for seventeen years, during which time he founded (in 1873) the Physical Society, which met at South Kensington for its first quarter of a century.⁸⁶ Guthrie was primarily an experimental, as opposed to mathematical, physicist with something of a mixed reputation as a teacher; some students found him helpful, but H. G. Wells, who also attended his lectures, described him as dull and slow, maundering "amidst ill-marshalled facts".⁸⁷ Following Guthrie's death in 1886, the professorship was held by the physicist Arthur Rücker (1848-1915) until 1901.

Thus far, much has been said of the physical sciences at the Royal College, but what of mathematics? Initially at least, training in mathematics was not a high priority, the emphasis being on practical as opposed to theoretical science. The chair of mathematics at the college eventually grew out of the professorship of mechanics which, in 1869, we find occupied by our old acquaintance Thomas Minchin Goodeve, fresh from losing his position at Woolwich. Goodeve's quarter of a century in South Kensington saw the publication of several textbooks on his subject: *Principles of Mechanics* (1874), *A Manual of Mechanics* (1886), and a popular *Text-Book on the*

⁸⁵ *The Royal Charter of the Imperial College of Science and Technology: Jubilee 1907-1957*, (London: Edson, 1957), 10.

⁸⁶ *D.N.B.*, **23**, 374-375.

⁸⁷ A. Rupert Hall, *Science for Industry: A Short History of the Imperial College of Science and Technology and Its Antecedents*, (London: Imperial College, 1982), 14.

Steam Engine (1879) which went through eleven editions. But despite this apparent endorsement, he received consistently unfavourable reviews as a lecturer, not mitigated by the fact that when he finally retired, in 1896, he was seventy-five years old.

His replacement in the chair (renamed Mechanics and Mathematics in 1881) was John Perry (1850-1920), an engineer who had previously taught at the Imperial College in Tokyo from 1875-1878 and later at the Technical College, Finsbury (see below). Another active textbook author, Perry also worked vigorously to develop demonstration apparatus for his mechanics classes, with the objective of bringing the disciplines of mathematics and engineering closer together. With this aim in view, it is not surprising that he was also the source of the following engaging quotation: "When I am among scientific men, I pose as a professional man - and when I am among professional people, I pose as a scientific man - and when I find both professional and scientific people together, I try to hold my tongue."⁸⁸

He is primarily remembered today as the leader of a large body of technical and applied mathematical teachers chiefly responsible for the complete divorce of Euclid and university education at the end of the Victorian era. In a speech to the British Association for the Advancement of Science at Glasgow in 1901, Perry vehemently attacked the restrictions imposed on the teaching of practical geometry by an examination system geared principally towards pure mathematicians: "I belong to a great body of men who apply the principles of mathematics in physical science and engineering; I belong to the very much greater body of men who may be called persons of average intelligence. In each of these capacities I need mental training and also mathematical knowledge."⁸⁹

To facilitate geometrical instruction, the "Perry Movement",⁹⁰ as it became known, urged for the total abandonment of Euclid in favour of a more utilitarian approach involving "greater use of intuitive and practical methods of proof in geometry, on the grounds of simplicity and because such methods *did* promote deductive reasoning".⁹¹ Perry's 1901 speech contained the following recommendations and comments:

⁸⁸ *ibid*, 27.

⁸⁹ John Perry (ed.), *British Association Meeting at Glasgow, 1901: Discussion on the Teaching of Mathematics*, (London: Macmillan and Co, 1902), 3-4.

⁹⁰ Florian Cajori, Attempts Made during the Eighteenth and Nineteenth Centuries to Reform the Teaching of Geometry, *American Mathematical Monthly*, **17** (1910), 181-201, p.197.

⁹¹ William H. Brock, Geometry and the Universities: Euclid and His Modern Rivals 1860-1901, *History of Education*, **4** (1975), 21-35, p.30.

1. Experimental geometry and practical mensuration to precede demonstrative geometry. Use of squared paper. Rough guessing at lengths and weights to be encouraged.
2. Some deductive reasoning to accompany experimental geometry.
3. More emphasis on solid geometry; this subject has been postponed too long.
4. Adoption of coordinate representation in space.
5. The introduction of trigonometric functions in the study of geometry.
6. Emphasis upon the utilitarian parts of the subject.
7. Examinations conducted by any other examiner than the pupil's teacher are imperfect examinations.⁹²

His address provoked a wave of discussion amongst mathematical teachers which appeared in the pages of journals such as *Nature* and the *Mathematical Gazette* throughout the first few years of the twentieth century. It also prompted the appointment of two committees, one of the British Association and one of the Mathematical Association (as the A.I.G.T. had recently been renamed), to decide on the matter. Perry did not have to wait long to witness the direct consequence of his outburst, however. In 1903, the examining board of the University of Cambridge decided to accept instead of Euclidean proofs, "any proof of the proposition, which appears to the Examiners to form part of a systematic treatment of the subject".⁹³ The University of London quickly followed suit. Almost overnight, the ascendancy of Euclidean geometry in English education had been overthrown because, as Joan Richards puts it, "the group for whom geometry was part of a practical education finally broke the power of those who defined its value strictly in terms of liberal education".⁹⁴

Perry's success in thus increasing the mathematical reputation of his college is evinced by the fact that not only was his successor in 1913 the first professional mathematician to teach there - Andrew Russell Forsyth (1858-1942) - but also the following year they were able to procure the services of another equally distinguished practitioner, Alfred North Whitehead (1861-1947). The recruitment of such eminent mathematicians demonstrated that, in mathematics, the Royal College of Science could now rival the previously unchallenged academic prestige of University College. However, the college at which Forsyth and Whitehead found themselves had nominally ceased to exist in 1907 when it was incorporated into the newly-formed Imperial College of Science and Technology. This had been created from the amalgamation of three South Kensington colleges specialising in scientific education,

⁹² Perry, *op. cit.*, (89), 97; Cajori, *op. cit.*, (90), 197-8.

⁹³ Brock, *op. cit.*, (91), 31.

⁹⁴ Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England*, (Boston: Academic Press, 1988), 198.

the other principal constituents being the Royal College of Mines and a third, more recent creation, which we shall now discuss.

7.5.3 The Central Technical College

At a meeting of the Livery Companies of the City of London at the Mansion House on 3 July 1876, the following resolution was passed: "That it is desirable that the attention of the Livery Companies be directed to the promotion of Education not only in the Metropolis but throughout the country, and especially to technical education, with the view of educating young artizans and others in the scientific and artistic branches of their trades."⁹⁵ The result was the formation by the various Guilds (such as the Mercers', Drapers' and Clothworkers' Companies) of the City and Guilds of London Institute for the Advancement of Technical Education in 1878.

The Institute's prime objective was the establishment of a central technical college in London, but acquiring a suitable site took more time than had been anticipated. As a stop-gap measure, in 1878, teaching began in Cowper Street, in an area slightly north of the city, called Finsbury. It was officially inaugurated in 1883 as The Technical College, Finsbury, with professorships in electrical engineering, chemistry, and mechanical engineering, the last of which was held by John Perry.⁹⁶ The college was brilliantly administered by Philip Magnus (1842-1933), another former De Morgan student, a University College graduate, and an educational reformer of exceptional organising ability.⁹⁷ Courses ran for between two and three years, tuition being based primarily in the workshop or laboratory. The majority of Finsbury students were, as intended, artisans, such as engineers, engravers, electricians, brewers, instrument makers and printers, numbering 100 in the session 1882-83 but increasing to 210 by 1894-95.⁹⁸ The college filled two complementary rôles: it served as a finishing technical school for those about to enter industrial life; and it operated as an intermediate college for those intending to go on to the proposed central technical college.

For this, the City and Guilds Institute finally secured a site on Exhibition Road from the 1851 Commissioners at a negligible rent. It eventually opened in 1884 as the Central Technical Institute (changed to the Central Technical College in 1893). The college was essentially a school of engineering with four professorships: chemistry,

⁹⁵ *A Short History of the City and Guilds of London Institute*, (London: City and Guilds of London Institute, 1896), 1.

⁹⁶ *ibid*, 6.

⁹⁷ Francis E. Foden, *Philip Magnus: Victorian Educational Pioneer*, (London: Vallentine, Mitchell, 1970).

⁹⁸ *op. cit.*, (95), 7.

physics (later electrical engineering), civil and mechanical engineering, and mechanics and mathematics.⁹⁹ Founding professor in this final chair was Olaus Henrici, who had been enticed from his post at University College. At South Kensington, he continued his teaching of projective geometry and vector analysis, also exploiting his new purpose-built premises to establish an innovative laboratory of mechanics upon which many later versions were based. Here he continued his research, developing among other things, a harmonic analyser, following a similar machine by Lord Kelvin, to calculate Fourier coefficients mechanically. He finally retired from the college in 1911.

Research, however, was not officially considered to be part of the professors' duties at the new institution, a restriction which caused some initial resentment. The explicit aim of the Central Technical College was to give practical instruction to

qualify persons to become -

1. Technical teachers;
2. Mechanical, civil and electrical engineers, architects, builders and decorative artists;
3. Principals, superintendents and managers of chemical and other manufacturing works....¹⁰⁰

Students, about half of whom came from the Finsbury college, entered at the age of sixteen or seventeen, being required to pass a matriculation examination where they were tested on physics, chemistry, drawing, mathematics, mechanics, and languages. This sounds quite a tall order, but no practicals were involved, and the standard of the tests was no higher than today's G.C.S.E. exams for the same age group. The course took three years to complete, with tuition taking place in the building's many laboratories, drawing offices, workshops, and lecture rooms. However, the overall level of instruction was far lower than its continental equivalents, largely because the professors at the college favoured a practical rather than theoretical approach: "The greater part of the teaching is not by lectures, but in the laboratory and workshop."¹⁰¹

Nevertheless, the Central Technical College soon established a high reputation. When its first courses began in January 1885, the number of full time students had been a mere six. This had rapidly increased, reaching 208 ten years later.¹⁰² By 1900, the college's premises, designed to accommodate two hundred students, were considerably overcrowded. Indeed, so wide had its standing grown that by 1902,

⁹⁹ Joyce Brown (ed.), *A Hundred Years of Civil Engineering at South Kensington*, (London: Civil Engineering Department, Imperial College, 1985), 18.

¹⁰⁰ Hall, *op. cit.*, (87), 24.

¹⁰¹ *ibid*, 25.

¹⁰² *op. cit.*, (95), 6.

students were coming from India, South Africa, Japan, Italy, and even from Germany, and paying substantial fees for the privilege (£35 per annum). It was the Central Technical College which was to form the third component of the new Imperial College upon its foundation in 1907, evolving into what is today its Faculty of Engineering.

7.5.4 Polytechnics

We now come, finally, to the provision of technical education for London's working population. In the 1830s, there had briefly existed in London an institution called "The Adelaide Gallery" after the wife of King William IV. This, while ostensibly being an educational establishment, was devoted more to the exhibition of new scientific instruments and curiosities than to scientific research or teaching. In 1838, an imitation was set up on Regent Street in central London. Titled the 'Polytechnic', it functioned along similar lines but with the addition of occasional popular lectures. Both institutions enjoyed periods of evanescent popularity and prosperity but after a few years eventually went bankrupt. In 1880, a wealthy philanthropist by the name of Quintin Hogg bought the Polytechnic's disused premises on Regent Street and reopened it under the same name but with a different agenda.

The new Regent Street Polytechnic now operated as a centre for the improvement of the working man with classes in science, art, and literature as well as physics and chemistry laboratories, a library, gymnasium and various sporting, religious, and educational clubs. Over 6,000 students enrolled in its first year; that number had risen to 15,000 by 1900. Like Birkbeck's Mechanics' Institute half a century before, the success of Hogg's Polytechnic inspired the foundation of similar polytechnics for the working population of London. In 1894, the London Polytechnic Council was formed to administer and partially fund the polytechnics. This body consisted of representatives from central government, the technical education board of the London County Council and the City and Guilds Institute, "and its duty was to consult as to the appropriation of funds, the organisation of teaching, the holding of needful examinations, and the supervision of the work generally".¹⁰³

Several of the London Guilds were instrumental in the foundation and administration of certain polytechnics; for example, the East London Technical College, founded at Mile End in 1884,¹⁰⁴ "steadily increased in numbers and influence under the fostering

¹⁰³ Joshua G. Fitch and William Garnett, Polytechnic, in *Encyclopædia Britannica*, 11th edition, **22**, (Cambridge: Cambridge University Press, 1911), 38-42, p.40.

¹⁰⁴ Wilson, *op. cit.*, (48), 66.

Table 4

London Polytechnics c.1900

1. Battersea Polytechnic
2. Birkbeck Literary and Scientific Institution
3. Borough Road Polytechnic
4. City of London College
5. East London Technical College
6. The Goldsmith's Institute
7. Northampton Institute
8. Northern Polytechnic
9. Regent Street Polytechnic
10. South-Western Polytechnic
11. Woolwich Polytechnic
12. Sir John Cass's Institute

care of the drapers' company"¹⁰⁵ while "the clothworkers' company ... also contributed £18,000 to the Northern Polytechnic at Holloway".¹⁰⁶ The Goldsmith's Institute at New Cross in south London, founded in 1894, "owed its existence and its annual maintenance to the generous initiative of the ancient guild whose name it bore".¹⁰⁷ The initial purpose of nearly all of these polytechnics was to provide basic mechanical and manual instruction for the working classes; but before long, more academic studies had been brought in to supplement the technical training.

This increase in the general range and quality of polytechnic courses coincided with significant alterations in the constitution of the University of London around the turn of the century which established it as a teaching as well as an examining university. These changes, resulting from the 1898 University of London Act, created the distinction between 'internal' and 'external' students. The former studied within the University for degrees awarded after the usual examinations, while those in the latter category were taught elsewhere, before then being examined by the University. As a consequence of this differentiation, the University's new statutes (which came into

¹⁰⁵ Fitch and Garnett, *op. cit.*, (103), 40.

¹⁰⁶ *ibid*, 41.

¹⁰⁷ *ibid*.

effect in 1900) permitted it to admit educational institutions of a certain standard as 'Schools of the University'.

Naturally, University and King's Colleges were included, together with many others, such as Bedford College for Women. The Central Technical College was also admitted as a University school in its Faculty of Engineering. But perhaps the most remarkable consequence of the University's new constitution was the admission of three polytechnics as schools of the University by 1907, namely, Birkbeck College, the East London College (now Queen Mary's College), and Goldsmith's College. This move was all the more desirable since "there were during the session 1906-1907 no less than eighty-six recognised 'teachers of the university' on the staffs of the London polytechnics and more than 750 students who were working for London University degrees in the polytechnic classes".¹⁰⁸

7.6 Concluding Comments

This chapter has aimed to survey the immense changes undergone by Britain's capital during the Victorian period. We have alluded to the great contrast in size between the cities of 1828 and 1900, where the population grew from 1½ to 4½ million people, and this is reflected in the huge increase in the number of institutions relevant to our subject during the intervening period. London and its environs had begun the Victorian era with a mere three institutions offering higher level mathematical tuition. By the beginning of the twentieth century, that number had increased to more than twenty, providing courses in mathematics no longer solely for purely academic or military purposes, but also for other facets of society such as industry and commerce.

This chapter has also shown that a study of mathematical education at university level can shed some light on social developments in the capital, particularly with respect to women and the working class. The majority of the new institutions created in Victorian London were designed to improve the education of at least one of these two groups, and these improvements to a certain extent mirrored the social and political fluctuations which occurred during the period. The changes which took place with regard to the mathematical education of women and the working classes both reflected and participated in the alteration of both groups' political status between the beginning and end of our period. In 1828, both parties were politically impotent having no right to vote, but by 1900, much of the working class population had

¹⁰⁸ *ibid.*

received the franchise and even women could vote in local government elections. However, it was the twentieth century which would witness the final progression (political and educational) which would aim to place women and workers on an equal footing with the rest of the population.

If we now turn our attention to the general characteristics of advanced mathematical tuition in Victorian London, several distinguishing features become apparent. One of the most striking is the number of prominent mathematical researchers who earned a living by teaching the subject at this time. Certainly, the capital had more than its fair share of the less academically distinguished as professors (such as Hall, Drew, Goodeve, etc.), but the fact remains that a remarkable number of top-rank mathematicians were also involved. Little explanation is required for this phenomenon, however. Throughout the nineteenth century, a mathematician could not support himself by research alone. Academics were paid solely to teach, and research constituted no part of a professor's duties.

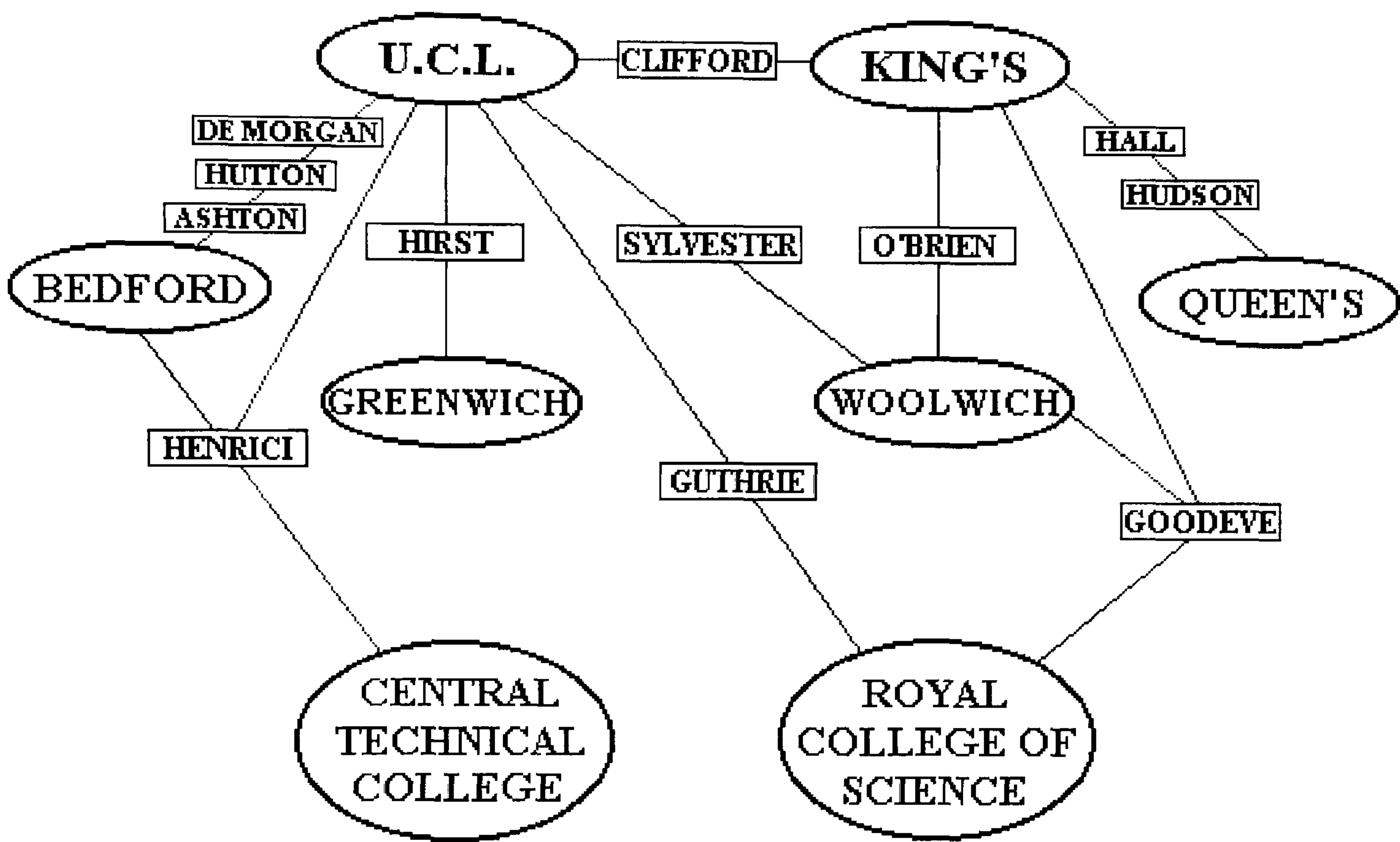
It is therefore hardly surprising that a considerable number of high-calibre London-based mathematicians chose to earn their living by teaching mathematics. In many cases, excellent researchers also proved to be equally successful teachers (for example, De Morgan, Clifford, Henrici, and Pearson). However, just as effective lecturing does not imply profound research, it is similarly true that not all skilled mathematicians made good teachers (as witness Maxwell and Sylvester). This is not to say that all mathematicians supported themselves by tuition: teaching appealed little enough to many of those engaged in it! Perhaps the best example of a London-based mathematical researcher who preferred not to teach is Arthur Cayley: he subsidised his research by working for twenty years as a lawyer. Even when appointed Sadlerian Professor at Cambridge in 1863, his lecturing duties were kept to an absolute minimum.

Table 5 serves as an illustration of another peculiarity of London mathematics at this time. The reader may have noticed the number of links and connections between the various institutions provided by the migration of different pupils or professors from institution to institution. For example, Sylvester was both a pupil and professor of natural philosophy at University College, and later professor of mathematics at Woolwich. Similarly, Clifford was a pupil of King's and a professor at University College. But not all connections are professorial: Hirst is linked to both University College and the Greenwich Naval College by having been professor of mathematics at the former and director of studies at the latter. While the links with other locations

would be equally interesting, it remains a testament to the growth of university-level mathematical instruction in this period that so many mathematicians were able to spend so much of their careers teaching within the same geographical area.

Table 5

London Links



If we had to choose one locality outside London to see its connections with the capital, the obvious place to pick would be Cambridge. A substantially high proportion of the principal characters in this thesis were, at some time in their careers, associated with the Cambridge mathematical community, either as staff, students, or both. Indeed it would be quicker to mention those involved in London mathematics who were *not* Cambridge men (such as Hirst, Henrici, Crofton, and Perry) than it would to list those who were. All the major London institutions of this period had at least one Cambridge graduate on their staff. Moreover, at King's College, no professor of mathematics or natural philosophy was appointed throughout the entire period who was not a wrangler. So the prevalence of Cambridge-trained mathematicians is one more characteristic of nineteenth-century London mathematics.

The dominance of University College mathematics has been stressed throughout this thesis and is another distinguishing feature of higher mathematical education in London during the period. It can be no coincidence, therefore, that the great majority

of eminent scholars who also happened to be good teachers were associated at one time or another with that institution. But there is one further tendency, prevalent not only in University College but in the other London institutions; that is, an increased inclination towards applied mathematics. In 1828, to receive tuition in 'mixed mathematics' at either of the two London institutions, it would have been necessary to pass through much of the grounding in pure mathematics before one could begin to deal with its applications. At Woolwich, the majority of the mathematics course was pure anyway, and the standard of the applied was scarcely adequate.

As the century progressed, however, the availability of advanced classes in applied mathematics rose sharply, especially with the inauguration of the technical colleges and polytechnics towards the latter part of the period. In these new institutions, thanks to the progressive methodology of professors such as John Perry, students were taught mathematics to facilitate construction, design, engineering, and other related disciplines, without reference to many of the abstract notions previously considered prerequisite for the study of applied mathematics. In the older establishments, the trend towards the applied side can also be detected. Most of the course innovations at University College after the 1870s took place in the applied department, while at Woolwich, the syllabus which had evolved by the 1890s was strikingly more applied than its predecessors. Thus, by the death of Queen Victoria, both the standard and availability of tuition in the applied branches of mathematics had increased dramatically. Consequently, as Britain entered the twentieth century, mathematics in London was more accessible and of more service to its population than ever before.

Appendix A

Inventory of De Morgan's Mathematical Tracts contained in the University of London Library

Shelf Mark	Tract No.	Class	Content	Date
MS.775/1	1	L.S.	Double Algebra	20 Nov 1852
MS.775/2	1	—	Algebra (Fundamentals)	1843
MS.775/3	2	—	Double Algebra	9 Nov 1847
MS.775/4	2	H.J./L.S.	Double Algebra	29 May 1855
MS.775/5	3	H.J.	Continued Fractions	1843
MS.775/6	3 ₁	H.J.	Continued Fractions	_____
MS.775/7	3 ₂	H.J.	Continued Fractions	_____
MS.775/8	4 ₁	H.J.	Ratio	_____
MS.775/9	4 ₁	H.J.	Ratio	_____
MS.775/10	4 ₂	H.J.	Ratio	_____
MS.775/11	4 ₃	H.J.	Ratio & Proportion	_____
MS.775/12	4 ₂	H.J.	Ratio	_____
MS.775/13	4 ₃	H.J.	Ratio & Proportion	_____
MS.775/14	4 ₄	H.J.	Ratio & Proportion	_____
MS.775/15	4 ₄	H.J.	Ratio & Proportion	20 Oct 1847
MS.775/16	4 ₅	H.J.	Ratio (Exercises)	8 Nov 1854
MS.775/17	4 ₆	H.J.	Euclid Book 5	18 Dec 1856
MS.775/18	4 ₇	H.J.	Prop ⁿ (Summary)	23 Oct 1858
MS.775/19	5	—	Probability Theory	8 Nov 1847
MS.775/20	5	H.S.	Error Theory	1 May 1862
MS.775/21	6	—	Probability Theory	8 Nov 1847
MS.775/22	6	H.S.	Error Theory	1 May 1862
MS.775/23	7 ₁	H.S.	Finite Integration	15 Nov 1847
MS.775/24	7 ₂	H.S.	Finite Integration	10 Nov 1854
MS.775/25	7 ₃	H.S.	Finite Integration	20 Nov 1857
MS.775/26	8	L.S.	Complex Numbers	18 Nov 1847
MS.775/27	8	L.S.	Complex Numbers	_____
MS.775/28	9	L.S.	Complex Numbers	_____
MS.775/29	9	L.S.	Complex Numbers	20 Nov 1847
MS.775/30	10	H.S.	Miscellaneous	22 Nov 1847
MS.775/31	11	H.S.	Integration	29 Nov 1848
MS.775/32	12	H.S.	Integration	30 May 1851

MS.775/33	13	—	Integration	6 Dec 1847
MS.775/34	13	L.S.	E.g.s of Integration	8 June 1855
MS.775/35	14	—	Generating Functions	9 Dec 1847
MS.775/36	14	H.S.	Generating Functions	9 Dec 1847
MS.775/37	15	H.S.	Differentiation	_____
MS.775/38	16 ₁	—	Projective Geometry	_____
MS.775/39	16 ₁	H.J.	Projective Geometry	30 July 1849
MS.775/40	16 ₂	—	Projective Geometry	_____
MS.775/41	16 ₂	H.J.	Projective Geometry	30 July 1849
MS.775/42	16 ₃	H.J.	Projective Geometry	4 Aug 1849
MS.775/43	17	L.S.	Polynomials	_____
MS.775/44	18	L.S.	Theory of Equations	_____
MS.775/45	19/20	L.S.	Theory of Equations	_____
MS.775/46	21 ₁	H.S.	Calculus of Functions	_____
MS.775/47	21 ₂	H.S.	Calculus of Functions	_____
MS.775/48	22	H.S.	Calc of Finite Diffs	_____
MS.775/49	23 ₁	H.S.	Calc of Finite Diffs	13 Jan 1857
MS.775/50	23 ₂	H.S.	Calc of Finite Diffs	_____
MS.775/51	23 ₃	H.S.	Calc of Operations	17 Jan 1855
MS.775/52	24	L.S.	Combinations	12 Jan 1848
MS.775/53	25	L.S.	Cauchy's Theorem	2 Feb 1848
MS.775/54	25 ₁	L.S.	Complex Analysis	20 Dec 1859
MS.775/55	25 ₂	L.S.	Complex Analysis	16 Nov 1857
MS.775/56	25 ₃	L.S.	Complex Analysis	3 Dec 1857
MS.775/57	25 ₄	L.S.	Algebraic version of 25 ₁	25 Jan 1861
MS.775/58	26	H.S.	Differential Equations	14 Feb 1848
MS.775/59	27 ₁	H.S.	Differential Equations	16 Feb 1857
MS.775/60	27 ₂	H.S.	Differential Equations	21 Feb 1848
MS.775/61	28	H.S.	Differential Equations	21 Feb 1849
MS.775/62	29	L.S.	Conic Sections	25 Apr 1848
MS.775/63	30	—	Conic Sections	1848
MS.775/64	30	L.S.	Conic Sections	5 Apr 1850
MS.775/65	31	—	Conic Sections	1848
MS.775/66	32 ₁	L.S.	Conic Sections	5 Apr 1850
MS.775/67	32	—	Conic Sections	1848
MS.775/68	33	—	Conic Sections	1848
MS.775/69	33 ₁	L.S.	Conic Sections	5 Apr 1850
MS.775/70	33 ₂	L.S.	Conic Sections	7 Apr 1856

MS.775/71	33 ₃	L.S.	Conic Sections	12 May 1855
MS.775/72	33 ₄	L.S.	Conic Sections	6 Mar 1861
MS.775/73	34	—	Projective Geometry	29 Feb 1848
MS.775/74	35	—	Projective Geometry	—————
MS.775/75	36	—	Projective Geometry	20 Mar 1848
MS.775/76	37	—	Projective Geometry	—————
MS.775/77	38	H.S.	Algebraic Geometry	15 Mar 1848
MS.775/78	39	—	Diff Eqns & Curves	23 Mar 1848
MS.775/79	39	H.S.	Diff Eqns & Curves	9 Mar 1855
MS.775/80	40	H.S.	Calculus Examples	27 Oct 1855
MS.775/81	40	—	2nd-degree Diff Eqns	31 Mar 1848
MS.775/82	41 ₁	H.S.	1st-order PDEs	23 Apr 1860
MS.775/83	41 ₂	H.S.	1st-order PDEs	6 Apr 1848
MS.775/84	41 ₃	H.S.	1st-order PDEs	10 Apr 1848
MS.775/85	43	H.S.	Differential Geometry	12 Apr 1848
MS.775/86	44	—	Differential Geometry	18 Apr 1848
MS.775/87	45	H.S.	Differential Geometry	19 Apr 1848
MS.775/88	46 ₁	H.S.	PDEs	21 Feb 1857
MS.775/89	46 ₂	H.S.	PDEs	27 Apr 1848
MS.775/90	47	—	Differential Geometry	6 May 1848
MS.775/91	48	H.S.	Definite Integrals	11 May 1848
MS.775/92	49	H.S.	Definite Integrals	16 May 1848
MS.775/93	50	H.S.	Definite Integrals	25 May 1848
MS.775/94	51 ₁	L.S.	Trigonometric Series	6 Dec 1855
MS.775/95	51 ₂	L.S.	Convergent Series	—————
MS.775/96	52 ₁	H.S.	Lagrange's Theorem	—————
MS.775/97	52 ₂	H.S.	Lagrange's Theorem	27 Nov 1855
MS.775/98	53 ₁	H.J./L.S.	Convergency of Series	9 Nov 1848
MS.775/99	53 ₁	H.J./L.S.	Convergency of Series	9 Nov 1848
MS.775/100	53 ₂	H.J./L.S.	Convergence (e.g.s)	1 Nov 1854
MS.775/101	53 ₃	L.S.	Divergent Series	1 Nov 1859
MS.775/102	53 ₃	H.J./L.S.	Divergent Series	1 May 1857
MS.775/103	53 ₄	H.J./L.S.	Convergence	1 Nov 1857
MS.775/104	53 ₅	L.S.	Summation of Series	1 Nov 1862
MS.775/105	54	—	Double Algebra	—————
MS.775/106	54	H.J.	Infinitesimals	6 Nov 1855
MS.775/107	55	L.S.	Conic Sections (Ellipse)	—————
MS.775/108	55	L.S.	Conic Sections (Ellipse)	—————

MS.775/109	56	L.S.	Conic Sections (Ellipse)	_____
MS.775/110	56	L.S.	Conic Sections (Ellipse)	_____
MS.775/111	57 ₁	H.S.	Integration	8 Dec 1848
MS.775/112	57 ₂	H.S.	Integration	6 May 1856
MS.775/113	58	L.S.	Con Sections (Parabola)	_____
MS.775/114	58	L.S.	Con Sections (Parabola)	_____
MS.775/115	59	L.S.	Con Sections (Hyperbola)	_____
MS.775/116	59	L.S.	Con Sections (Hyperbola)	_____
MS.775/117	60	L.S.	Con Sections (Hyperbola)	_____
MS.775/118	60	L.S.	Con Sections (Hyperbola)	_____
MS.775/119	61 ₁	H.J.	Perms and Combs	6 Aug 1849
MS.775/120	61 ₂	H.J.	Perms and Combs	15 Aug 1849
MS.775/121	61 ₃	H.J.	Perms and Combs	18 Aug 1849
MS.775/122	62	H.J.	Probability (Exercises)	31 Aug 1849
MS.775/123	62	H.J.	Probability (Exercises)	30 Jan 1849
MS.775/124	63	H.J.	Probability (Exercises)	6 Feb 1849
MS.775/125	63	H.J.	Probability (Exercises)	31 Aug 1849
MS.775/126	64	H.S.	Taylor's Theorem	15 May 1849
MS.775/127	65	H.S.	Implicit Differentiation	22 May 1849
MS.775/128	66	H.J.	Linear Algebraic Eqns	25 May 1849
MS.775/129	66	H.J.	Linear Algebraic Eqns	30 Aug 1849
MS.775/130	67	—	Curvature	30 May 1849
MS.775/131	68	H.S.	Probability Theory	2 June 1849
MS.775/132	69 ₁	H.S.	Probability Theory	6 June 1849
MS.775/133	69 ₂	H.S.	Probability Theory	6 June 1853
MS.775/134	70	—	Algebraic Geometry	_____
MS.775/135	71	H.J.	Polynomials	18 Aug 1849
MS.775/136	72	H.J.	Polynomials	20 Aug 1849
MS.775/137	73	H.S.	3-D Algebraic Geometry	31 Aug 1849
MS.775/138	74	H.S.	3-D Algebraic Geometry	4 Sept 1849
MS.775/139	75	H.S.	3-D Algebraic Geometry	8 Sept 1849
MS.775/140	76	H.S.	3-D Algebraic Geometry	10 Sept 1849
MS.775/141	77	H.S.	3-D Algebraic Geometry	10 Sept 1849
MS.775/142	78	H.S.	3-D Algebraic Geometry	15 Sept 1849
MS.775/143	79	—	3-D Algebraic Geometry	18 Sept 1849
MS.775/144	80	—	3-D Algebraic Geometry	20 Sept 1849
MS.775/145	81	—	3-D Algebraic Geometry	24 Sept 1849
MS.775/146	82	—	3-D Algebraic Geometry	25 Sept 1849

MS.775/147	83	H.S.	Extension of word 'Area'	28 Sept 1849
MS.775/148	84	H.J.	Interest & Annuities	1 Oct 1849
MS.775/149	85	H.J.	Interest & Annuities	2 Oct 1849
MS.775/150	86 ₁	H.S.	Miscellaneous Problems	9 Nov 1849
MS.775/151	86 ₂	H.S.	Miscellaneous Problems	_____
MS.775/152	86 ₃	H.S.	Miscellaneous Problems	_____
MS.775/153	86 ₄	H.S.	Miscellaneous Problems	16 Mar 1850
MS.775/154	86 ₅	H.S.	Miscellaneous Problems	20 Apr 1850
MS.775/155	86 ₆	H.S.	Miscellaneous Problems	5 Dec 1850
MS.775/156	86 ₇	H.S.	Miscellaneous Problems	12 Dec 1850
MS.775/157	87 ₁	L.S.	Miscellaneous Problems	_____
MS.775/158	87 ₂	L.S.	Miscellaneous Problems	17 Dec 1849
MS.775/159	87 ₃	L.S.	Miscellaneous Problems	_____
MS.775/160	87 ₄	L.S.	Miscellaneous Problems	6 May 1851
MS.775/161	88	L.J.	Euclid Book 2	_____
MS.775/162	89 ₁	H.S.	1st-order Diff Eqns	13 Nov 1850
MS.775/163	89 ₂	H.S.	1st-order Diff Eqns	13 Nov 1850
MS.775/164	89 ₂	H.S.	1st-order Diff Eqns	6 Dec 1853
MS.775/165	90 ₁	H.J.	Theory of Equations	15 Apr 1850
MS.775/166	90 ₂	H.J.	Theory of Equations	17 Apr 1856
MS.775/167	91	L.J.	Remarks on Euclid 1-6	4 Nov 1850
MS.775/168	91	L.J.	Remarks on Euclid 1-6	4 Nov 1850
MS.775/169	92	H.S.	Integration	22 Nov 1850
MS.775/170	92 ₂	L.S./H.S.	Integration	8 May 1866
MS.775/171	93	H.S.	Integration	25 Jan 1851
MS.775/172	94 ₁	H.S.	1st-order Diff Eqns	7 Feb 1851
MS.775/173	94 ₂	H.S.	Singular Solutions	20 Feb 1855
MS.775/174	95	—	Taylor's Theorem	7 Feb 1851
MS.775/175	96 ₁	H.S.	Double Integration	25 Feb 1851
MS.775/176	96 ₂	H.S.	Solids & Surfaces	20 Mar 1857
MS.775/177	97	H.S.	2-D Algebraic Geometry	6 Mar 1851
MS.775/178	98 ₁	H.S.	Curves and Surfaces	7 Apr 1851
MS.775/179	98 ₂	H.S.	Curves and Surfaces	7 Apr 1851
MS.775/180	98 ₃	H.S.	Curves and Surfaces	7 Apr 1851
MS.775/181	98 ₄	H.S.	Curves and Surfaces	8 Apr 1851
MS.775/182	98 ₅	H.S.	Curves and Surfaces	_____
MS.775/183	99	L.S./H.S.	Taylor & Maclaurin	31 Oct 1854
MS.775/184	99	—	Proof of Taylor's Thm	5 May 1851

MS.775/185	100 ₁	H.S.	Calculus of Variations	6 May 1851
MS.775/186	100 ₂	H.S.	Calculus of Variations	6 May 1851
MS.775/187	100 ₃	H.S.	Calculus of Variations	6 May 1851
MS.775/188	102	L.S./H.S.	Differentiation	20 Nov 1851
MS.775/189	103	H.S.	2nd-order Diff Eqns	6 Feb 1852
MS.775/190	104	H.S.	PDEs	6 Feb 1852
MS.775/191	105 ₁	L.S.	Algebraic Geometry	27 Apr 1852
MS.775/192	105 ₂	L.S.	Algebraic Geometry	27 Apr 1852
MS.775/193	105 ₃	L.S.	Algebraic Geometry	27 Apr 1852
MS.775/194	105 ₄	L.S.	Algebraic Geometry	27 Apr 1852
MS.775/195	105 ₅	L.S.	Algebraic Geometry	27 Apr 1852
MS.775/196	106	H.J.	Theory of Equations	3 May 1852
MS.775/197	107 ₁	L.S.	Rules of Differentiation	1 Apr 1857
MS.775/198	107 ₂	L.S./H.S.	Summary of Diff ⁿ	21 Oct 1852
MS.775/199	108	L.S./H.S.	Differential Coefficients	26 Oct 1852
MS.775/200	109	L.S./H.S.	Maclaurin's Theorem	2 Nov 1852
MS.775/201	110 ₁	L.J.	Notions prior to geometry	15 Oct 1858
MS.775/202	110 ₂	L.J.	Geometrical Reasoning	5 Feb 1853
MS.775/203	110 ₃	L.J.	Universal Affirmatives	16 Nov 1855
MS.775/204	111	H.J.	Perspective	28 Feb 1860
MS.775/205	112	—	Projective Geometry	21 Apr 1853
MS.775/206	112	L.S.	Projective Properties	23 Apr 1855
MS.775/207	113	H.J./L.S.	Logarithms	23 May 1853
MS.775/208	114	H.S.	Integration (Examples)	2 June 1853
MS.775/209	115 ₁	H.S.	Calculus of Operations	24 Oct 1854
MS.775/210	115 ₂	H.S.	Calculus of Operations	26 Nov 1853
MS.775/211	116 ₁	L.S.	Spherical Trigonometry	19 Dec 1855
MS.775/212	116 ₂	L.S.	Spherical Trigonometry	9 Dec 1853
MS.775/213	116 ₃	L.S.	Spherical Trigonometry	13 Dec 1856
MS.775/214	117	L.S.	Theory of Equations	24 Feb 1854
MS.775/215	117	L.S.	Theory of Equations	6 Mar 1854
MS.775/216	118	L.S.	Algebraic Geometry	25 Feb 1854
MS.775/217	119	H.S.	Determinants	7 Mar 1854
MS.775/218	120	H.S.	Implicit Differentiation	7 Mar 1854
MS.775/219	121	H.S.	Radius of Curvature	10 Mar 1854
MS.775/220	122	H.J.	Algebraic Geometry	14 Mar 1854
MS.775/221	123 ₁	H.S.	2nd-order Diff Eqns	28 Mar 1854
MS.775/222	123 ₂	H.S.	2nd-order Diff Eqns	28 Mar 1854

MS.775/223	123 ₃	H.S.	2nd-order Diff Eqns	28 Mar 1854
MS.775/224	124	H.J.	Exponents (Exercises)	30 Mar 1854
MS.775/225	125 ₁	H.J.	Trigonometry (Exercises)	10 Apr 1854
MS.775/226	125 ₂	H.J.	Trigonometry (Exercises)	14 May 1855
MS.775/227	126 ₁	H.S.	Diff Eqns (Exercises)	10 Apr 1854
MS.775/228	126 ₂	H.S.	Diff Eqns (Exercises)	10 Apr 1854
MS.775/229	126 ₃	H.S.	Diff Eqns (Exercises)	23 Oct 1854
MS.775/230	127 ₁	L.S./H.S.	Infinitesimals	_____
MS.775/231	127 ₂	H.S.	Infinitesimals	24 Nov 1856
MS.775/232	127 ₃	H.S.	Infinitesimals	24 Nov 1856
MS.775/233	128	L.S./H.S.	Maclaurin Series	28 Apr 1854
MS.775/234	128 ₂	L.S./H.S.	Maclaurin Series	28 Oct 1863
MS.775/235	129	H.J./L.S.	Binomial Theorem	4 Nov 1854
MS.775/236	130	H.S.	Diff Eqns (Exercises)	15 Dec 1854
MS.775/237	131 ₁	H.S.	Infinitesimals	10 Jan 1855
MS.775/238	131 ₂	H.S.	Infinitesimals	10 Jan 1855
MS.775/239	132 ₁	L.S.	Fourier/Sturm's Thms	10 Jan 1855
MS.775/240	132 ₂	L.S.	Fourier/Sturm's Thms	10 Jan 1855
MS.775/241	133	H.J.	Theory of Equations	10 Jan 1855
MS.775/242	134	H.S.	Theory of Equations	10 Jan 1855
MS.775/243	135 ₁	L.S.	Theory of Equations	28 Feb 1855
MS.775/244	135 ₂	H.S.	Theory of Equations	10 Jan 1855
MS.775/245	136	L.S.	Theory of Equations	23 Jan 1855
MS.775/246	137 ₁	H.S.	Integration (Examples)	9 Feb 1855
MS.775/247	137 ₂	H.S.	Diff Eqns (Examples)	16 Feb 1855
MS.775/248	138	L.J.	Euclid Book 3	22 Feb 1855
MS.775/249	139	L.S.	Algebraic Geometry	12 Mar 1855
MS.775/250	140 ₁	H.S.	Singular points of curves	26 Mar 1855
MS.775/251	140 ₂	H.S.	Singular points of curves	26 Mar 1855
MS.775/252	140 ₃	H.S.	Singular points of curves	3 Mar 1857
MS.775/253	140 ₄	H.S.	Singular points of curves	26 Mar 1855
MS.775/254	140 ₅	H.S.	Singular points of curves	31 Mar 1856
MS.775/255	141	L.S.	Proj ⁿ of Maps & Charts	26 Apr 1855
MS.775/256	142	H.S.	2nd-order Surfaces	5 May 1855
MS.775/257	143	L.S./H.S.	Intro to Diff Eqns	11 June 1855
MS.775/258	144	L.S.	Inverse Functions	10 Nov 1855
MS.775/259	145 ₁	L.S.	Neutral Series	20 Nov 1863
MS.775/260	145 ₂	L.S.	Series & Functions	6 Dec 1855

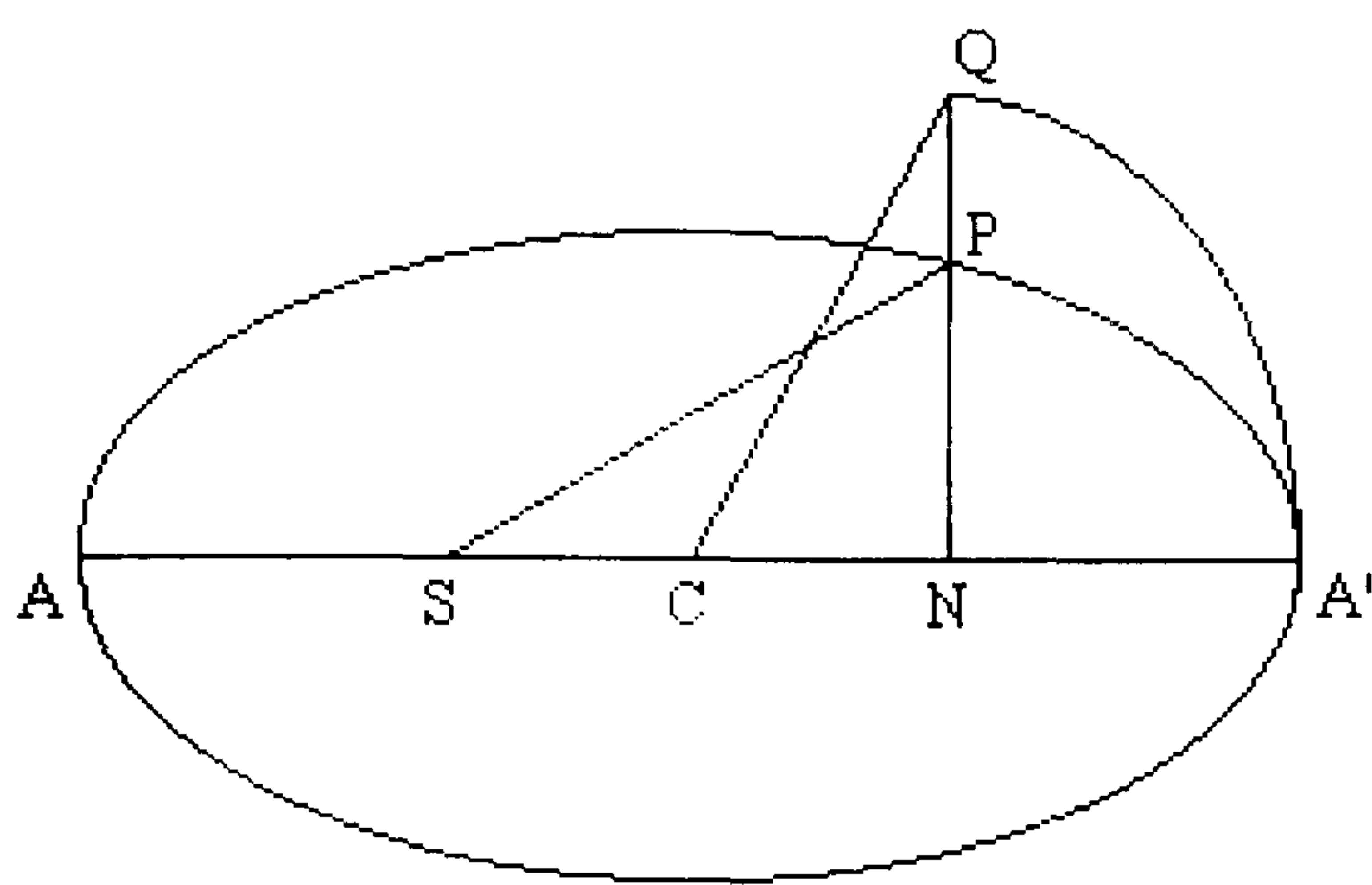
MS.775/261	146 ₁	L.S.	Projection (Elements)	30 Jan 1856
MS.775/262	146 ₂	L.S.	Projection (Conics)	30 Jan 1856
MS.775/263	146 ₃	L.S.	Projection (Conics)	19 Feb 1856
MS.775/264	146 ₄	L.S.	Projection (Conics)	8 Mar 1856
MS.775/265	146 ₅	L.S.	Projection (Conics)	8 Mar 1856
MS.775/266	147 ₁	H.S.	Diff Eqns (higher degree)	26 Feb 1856
MS.775/267	147 ₂	H.S.	Diff Eqns (higher degree)	23 Feb 1860
MS.775/268	148	H.J./L.S.	Algebra (Fundamentals)	13 Mar 1856
MS.775/269	149	H.J.	Linear Equations	15 Mar 1856
MS.775/270	150	L.J./H.J.	Linear Equations	19 Mar 1855
MS.775/271	151	H.J./L.S.	Arithmetic/Algebra	31 Mar 1856
MS.775/272	152	L.J./H.J.	Polynomials	5 Apr 1856
MS.775/273	153	L.S.	Theory of Equations	29 Apr 1856
MS.775/274	154	H.J./L.S.	Series Expansions	22 May 1856
MS.775/275	155	L.S.	Differentiation (Exercises)	6 Oct 1856
MS.775/276	156	H.J.	Arith ^l & Geom ^l Progression	9 Dec 1856
MS.775/277	157	L.J.	Abstract/Concrete Arithmetic	9 Dec 1856
MS.775/278	158	L.S.	Properties of Polyhedra	18 Dec 1856
MS.775/279	159	H.S.	Maxima & Minima	20 Dec 1856
MS.775/280	160	H.J./L.S.	Properties of Polyhedra	17 Jan 1857
MS.775/281	161 ₁	H.J.	Solid Geometry	22 Jan 1857
MS.775/282	161 ₂	H.J.	Solid Geometry	29 Jan 1857
MS.775/283	161 ₃	H.J.	Solid Geometry	11 Feb 1857
MS.775/284	162	H.J./L.S.	Limits	8 Apr 1857
MS.775/285	163	H.J.	Trigonometry	24 Apr 1857
MS.775/286	164	H.J./L.S.	Equivalent Series	5 May 1857
MS.775/287	165 ₁	L.S.	Spherical Trigonometry	30 Nov 1857
MS.775/288	165 ₂	L.S.	Spherical Trigonometry	9 Dec 1864
MS.775/289	166	H.S.	Convergent/Divergent Series	19 Dec 1857
MS.775/290	167	L.S.	Theory of Equations	4 Feb 1858
MS.775/291	168	H.S.	Simultaneous Diff Eqns	24 Feb 1858
MS.775/292	169 ₁	H.J./L.S.	Projective Geometry	19 Mar 1858
MS.775/293	169 ₂	H.J./L.S.	Projective Geometry	19 Mar 1858
MS.775/294	169 ₃	H.J./L.S.	Projective Geometry	27 Mar 1858
MS.775/295	170	L.S./H.S.	Differentiation	12 May 1858
MS.775/296	171	L.S.	Intro to Diff Eqns	5 June 1858
MS.775/297	172 ₁	H.S.	Velocity & Acceleration	28 Oct 1858
MS.775/298	172 ₂	H.S.	Velocity & Acceleration	25 Jan 1861

MS.775/299	173 ₁	H.J.	Probability (Examples)	4 Mar 1859
MS.775/300	173 ₂	H.J.	Probability (Examples)	4 Mar 1859
MS.775/301	174 ₁	H.S.	Differential Equations	19 Jan 1860
MS.775/302	174 ₂	H.S.	Differential Equations	17 Mar 1859
MS.775/303	175 ₁	L.S.	Music Theory	28 Dec 1857
MS.775/304	175 ₂	L.S.	Music Theory	28 Dec 1857
MS.775/305	186	H.J.	Summation of Series	7 Apr 1864
MS.775/306	——	L.S.	Projection (Summary)	5 Apr 1864
MS.775/307	——	H.S.	Neutral Series	27 Dec 1865
MS.775/308	——	——	Polygons	——
MS.775/309	——	——	Polygons	——
MS.775/310	——	——	Euclid's reasoning in Bk I	——
MS.775/311	——	——	Euclid's reasoning in Bk II	——
MS.775/312	——	——	Reduction of PDEs to ODEs	——
MS.775/313	——	——	Reduction of PDEs to ODEs	——
MS.775/314	——	——	Projective Geometry (Intro)	——
MS.775/315	——	——	Projective Geometry	——
MS.775/316	——	——	Curves and Diff Eqns	——
MS.775/317	——	——	Miscellaneous Problems	——
MS.775/318	——	——	Convergence of Series	——
MS.775/319	——	——	Summation of Series	——
MS.775/320	——	——	Double Algebra	——
MS.775/321	——	——	Division of Polynomials	——
MS.775/322	——	——	Indeterminate Equations	——
MS.775/323	——	——	Double Algebra	——
MS.775/324	——	——	Curves and Surfaces	——

Appendix B

Lectures on Algebraic Geometry and the Calculus, delivered in University College, London, by Prof. A. De Morgan. Session 1846-1847.*

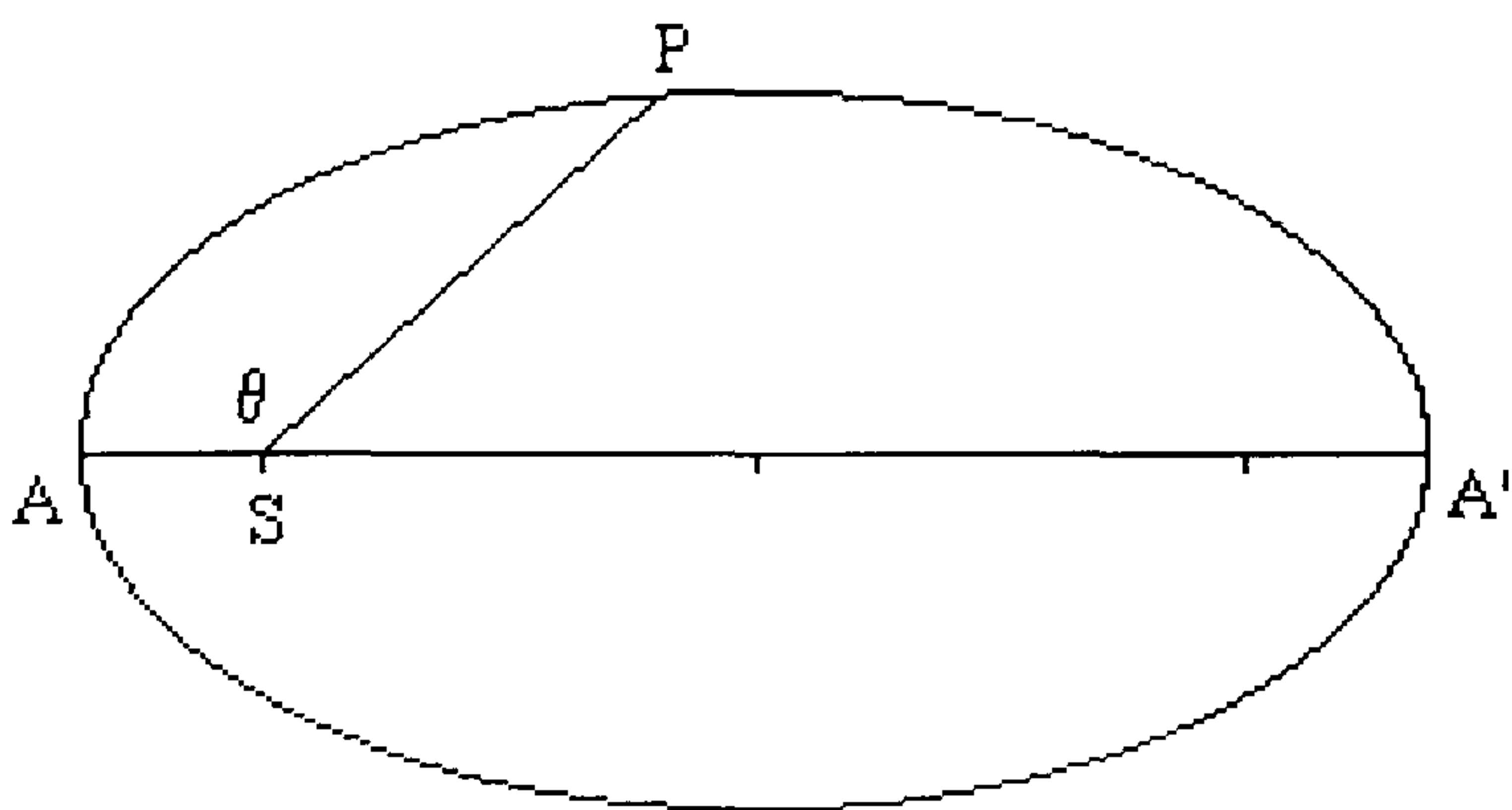
Lecture 57. March 13th 1847



$$\begin{aligned} ANP &= \frac{ab}{2}(\varphi - \sin \varphi \cos \varphi) \\ ASP &= \frac{ab}{2}(\varphi - e \sin \varphi) \end{aligned}$$

Keppler's Laws. -

- Planets move round sun in ellipses of small eccentricity, of which the sun is a focus.
But the ellipse is itself undergoing slow changes.
- The law of the motion is that equal areas are described in equal time.
- The squares of the times are to one another as the cubes of the mean distances.
 $t^2 : t'^3 :: a^3 : a'^3.$



* University College London Archives, MS.ADD.5, ff. 8-14, 16-19.

Let whole time of planets revolution = T = complete revolution.

Average time of revolution in one day = $\frac{2\pi}{T} = n$:= the average angular motion in one day, called "mean motion" in Astronomy.

Let time of describing ASP = t .

Average motion in t days = nt .

This has name of mean anomaly.

Areas are proportional to times

$$\therefore \text{Area ASP} : \text{Area ellipse} :: t : T$$

$$\frac{t}{T} = \frac{\text{ASP}}{\text{ellipse}} = \frac{\frac{ab}{2}(\varphi - e \sin \varphi)}{\pi ab} = \frac{\varphi - e \sin \varphi}{2\pi}$$

$$nt = \varphi - e \sin \varphi, \text{ for } n = \frac{2\pi}{T}$$

(N.B.) n is in theoretical units. The average angular motion in *one* day.

nt is the mean anomaly = $\angle w^h$ would have been desc^d in t days if the planet had had its mean or average motion.

Given where planet is, required the number of days, taken to come there.

Given θ find φ for $\tan \frac{\theta}{2} = \sqrt{\frac{1+e}{1-e}} \cdot \tan \frac{\varphi}{2}$, given $\theta = 100^\circ$.

Do this,

$$\begin{array}{ll} a = 16.71 & \text{find number of days} \\ e = .0943 & \text{it has come from} \\ T = 431.2 & \text{perihelion.} \end{array}$$

Find φ , turn it into theoretical units & subtract $e \sin \varphi$ divide by n & you have number of days it takes the planet to come from perihelion.

Converse. Given number of days find place of the planet.

Having found φ , we have 2 =^{ns} to determine θ & r , viz

$$\tan \frac{\theta}{2} = \sqrt{\frac{1+e}{1-e}} \cdot \tan \frac{\varphi}{2}$$

$$r = a(1 - e \cos \varphi)$$

{If a planet desc^s = areas in = times about S, ecc^y being small, = $\angle s$ will be much more nearly desc^d about H than about S.}

The eccentricity is generally very small (except in case of comets = 1 nearly) if e be small.

$$\varphi = c + e \sin \varphi$$

$$\varphi = c \text{ nearly } (c = \text{mean anomaly})$$

$\therefore \varphi = c + e \sin c$, more nearly, for in first $\varphi = c$. Our error nearly = $e \sin c$. This error in new solution is less than before. Suppose $e = \frac{1}{10}$, whatever error you make in $\sin \varphi$, you only make $\frac{1}{10}$ part of that error in $e \sin \varphi$.

$$\varphi = c + e \sin (c + e \sin c) \text{ more nearly still}$$

$$= c + e(\sin c + \cos c \cdot e \sin c)$$

$$= c + e \sin c + e^2 \sin c \cdot \cos c.$$

$\varphi = c + e \sin(c + e \sin c + e^2 \sin c \cdot \cos c)$ now develops this to terms of 3rd order.

$$= c^2 + e \left\{ \sin c \left(1 - \frac{e^2 \sin^2 c}{2} \right) + \cos c (e \sin c + e^2 \sin c \cos c) \right\} + e^3 \left(\sin c \cos^2 c - \frac{\sin^3 c}{2} \right) \sin c \frac{2 \cos^2 c - \sin^2 c}{2}$$

$$\therefore \varphi = c + e \sin c + e^2 \sin c \cos c + \frac{e^3}{2} \sin c (2 - 3 \sin^2 c)$$

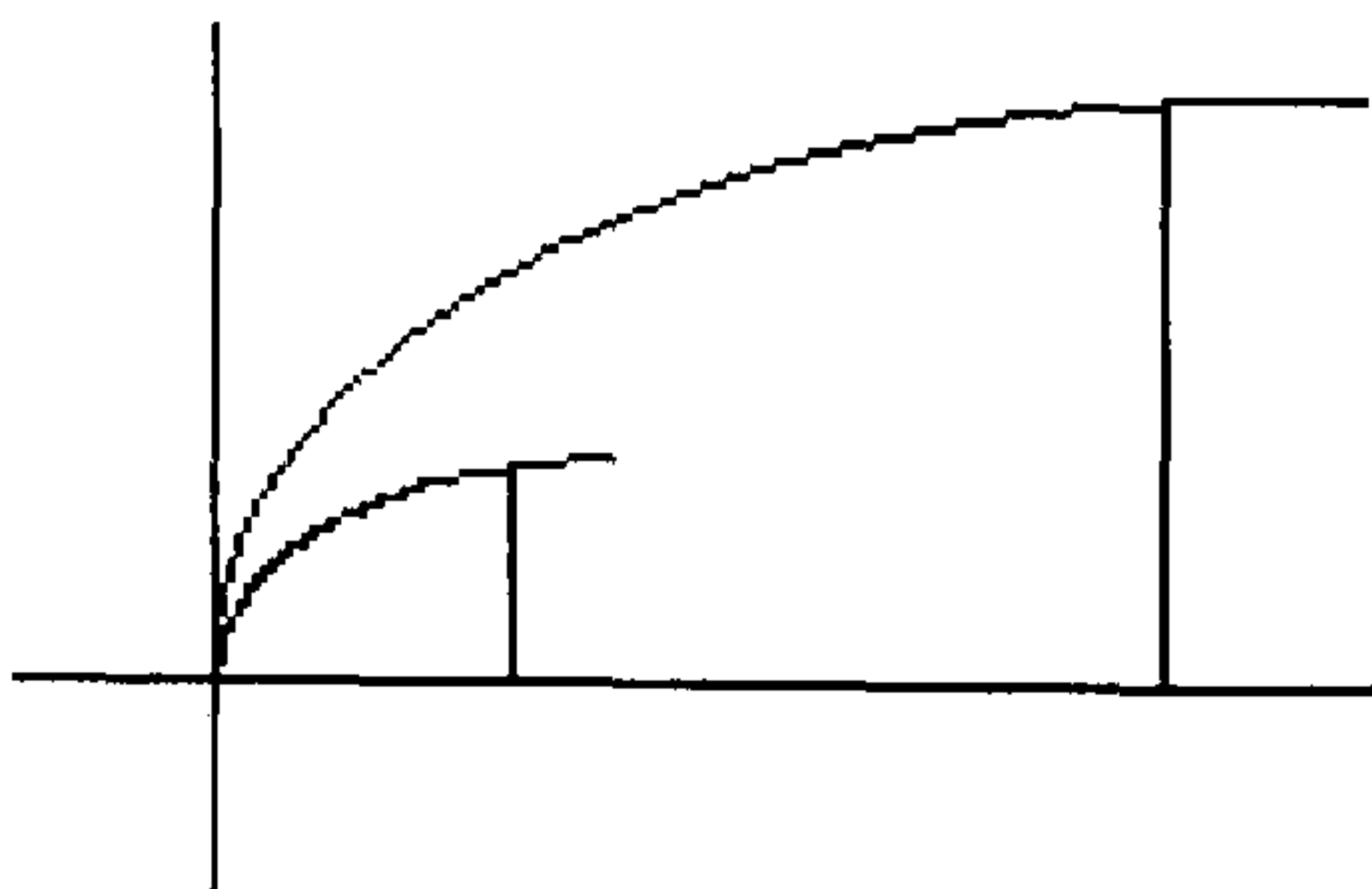
{Carry it one step further yourself.}

{And where the planet will be in 100 days - as far correct as the above formula.}

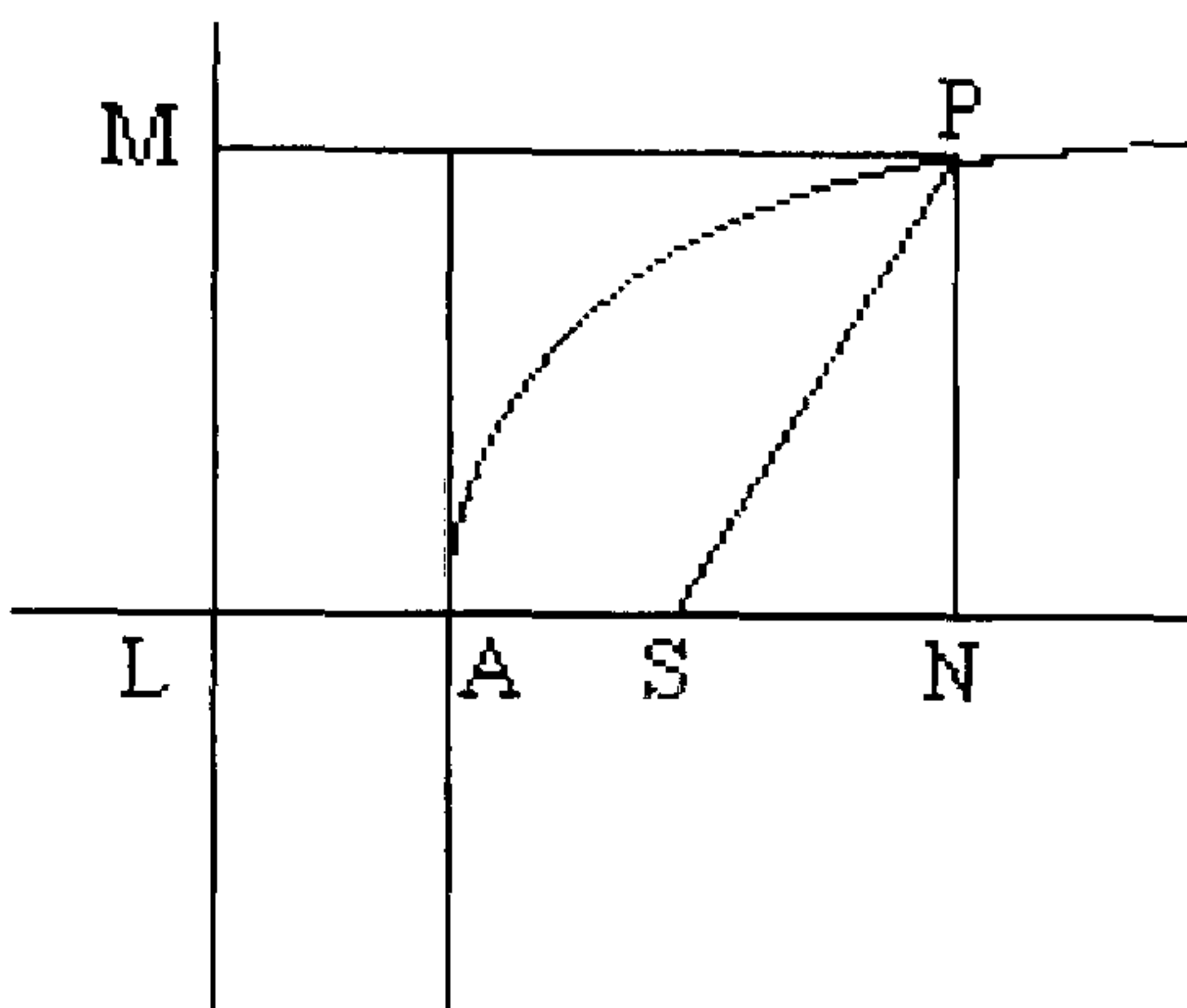
From φ thus found, find θ & r .

The Parabola

All parabolas are similar curves differing only in magnitude.



The parabola is only an extreme case of the ellipse. The orbits of comets were considered to be parabolas.

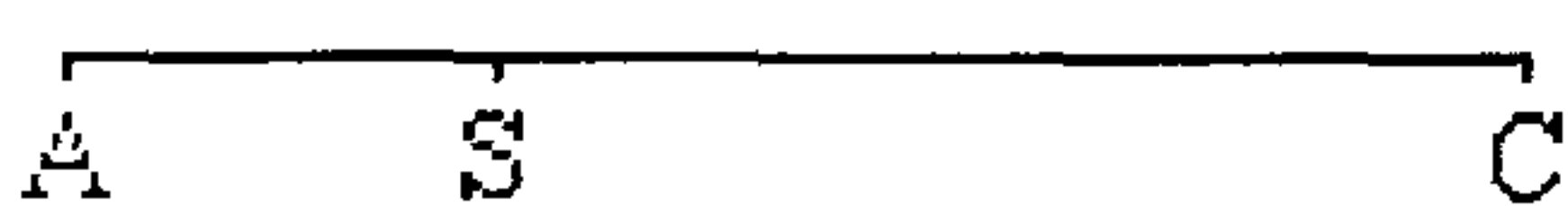


In Parabola $e = 1$
 $SP = PM$

In general $=^n$ was
 $y^2 = 2c(1 + e)x + (e^2 - 1)x^2$ when $e = 1$
 $y^2 = 4cx$

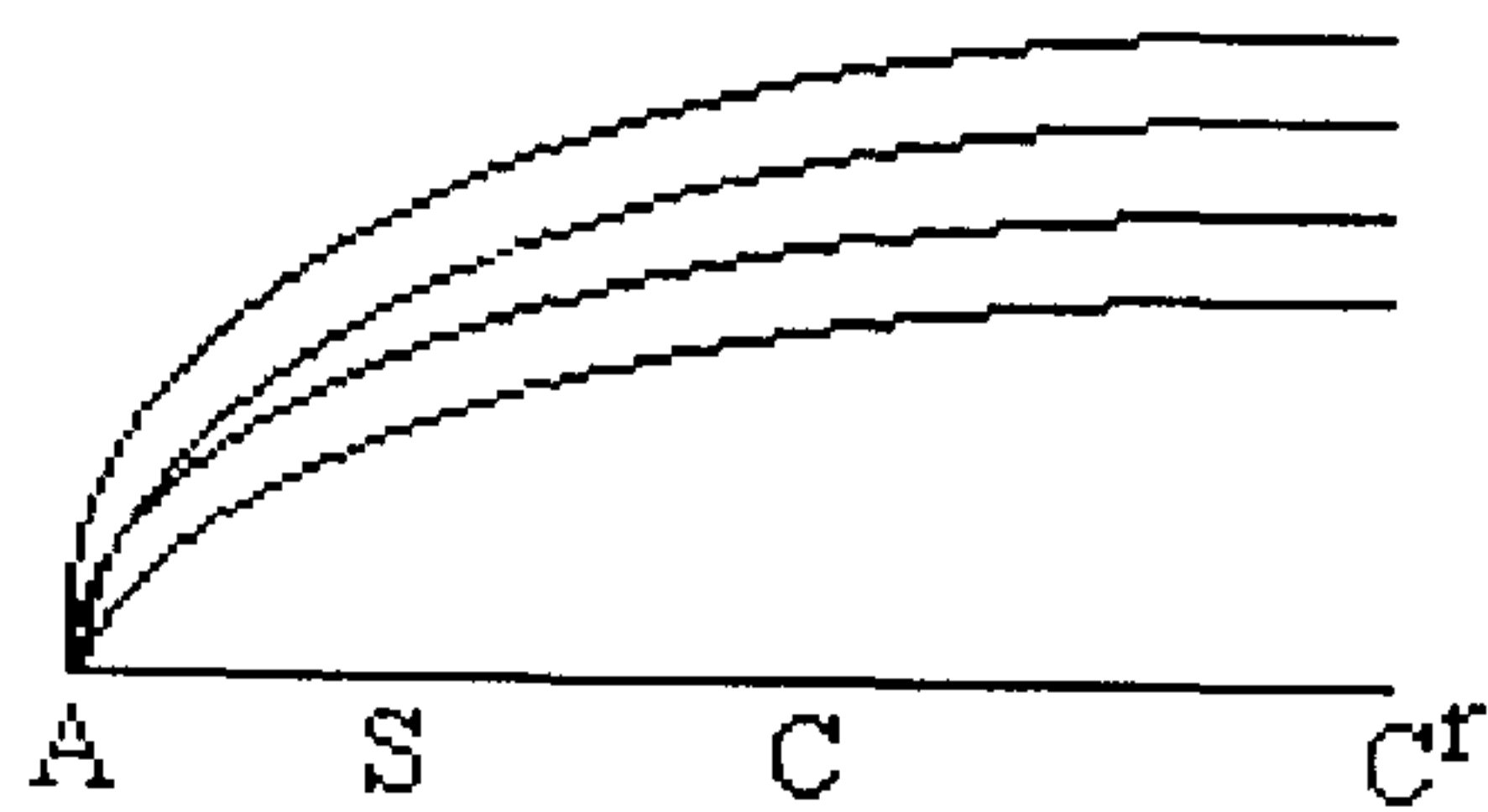
$$\begin{aligned} AN = x \text{ } AL = c = AS \\ \therefore \overline{x - c}^2 + y^2 &= \overline{c + x}^2 \\ \text{or } y^2 &= 4cx \text{ again.} \end{aligned}$$

I'll shew now that it is an ellipse, with the other focus moved off to an infinite distance. Suppose e is a very little less than one. You might take an ellipse with eccentricity so nearly $= 1$ that the ellipse shall coincide with the parabola till $x =$ a million miles.

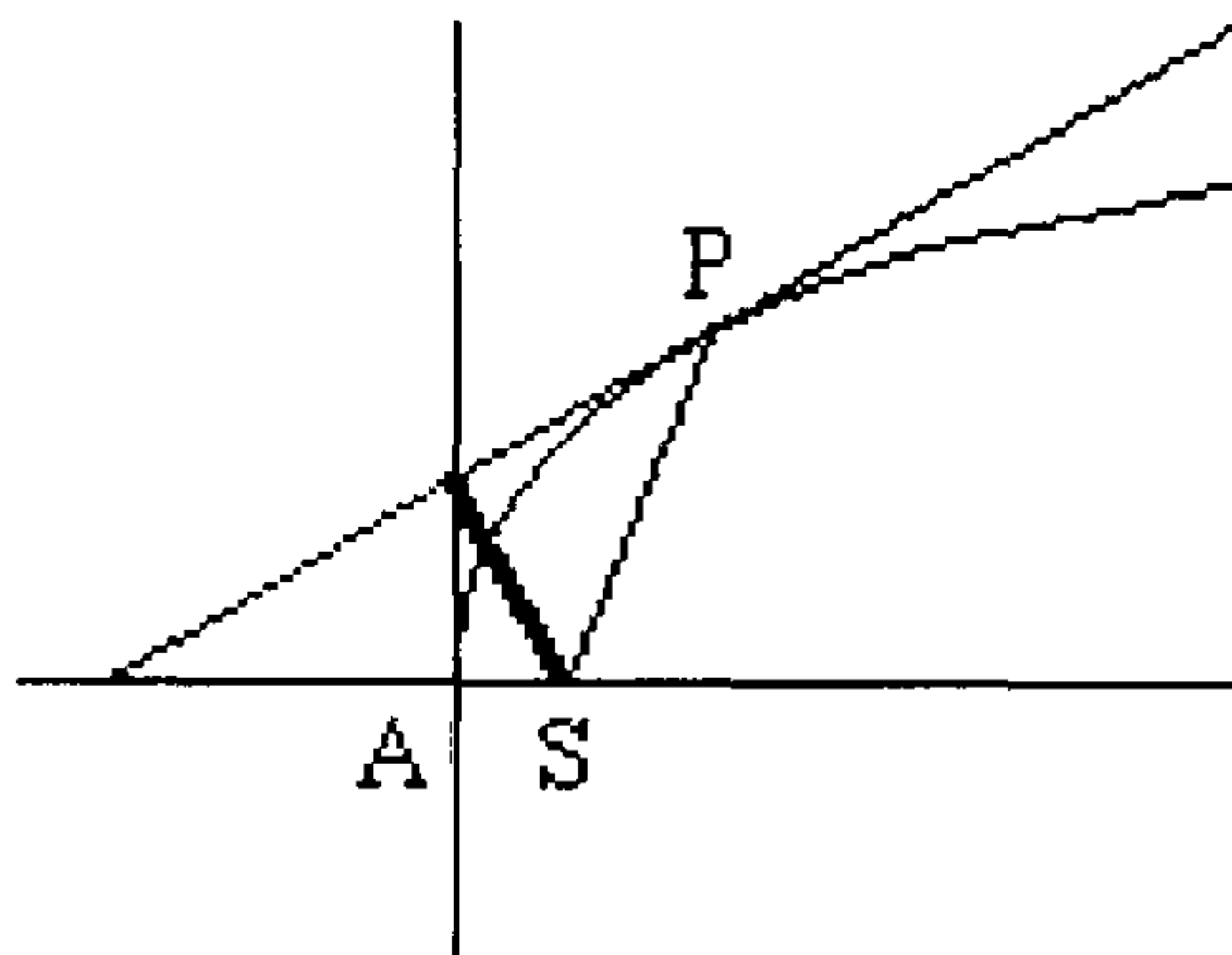


$$e = \frac{CS}{CA}$$

The farther off you move C the nearer does $CS = CA$, but never $=$ it; therefore the farther off you take C the nearer do you get to the parabola. Therefore the parabola is the boundary of all the ellipses.

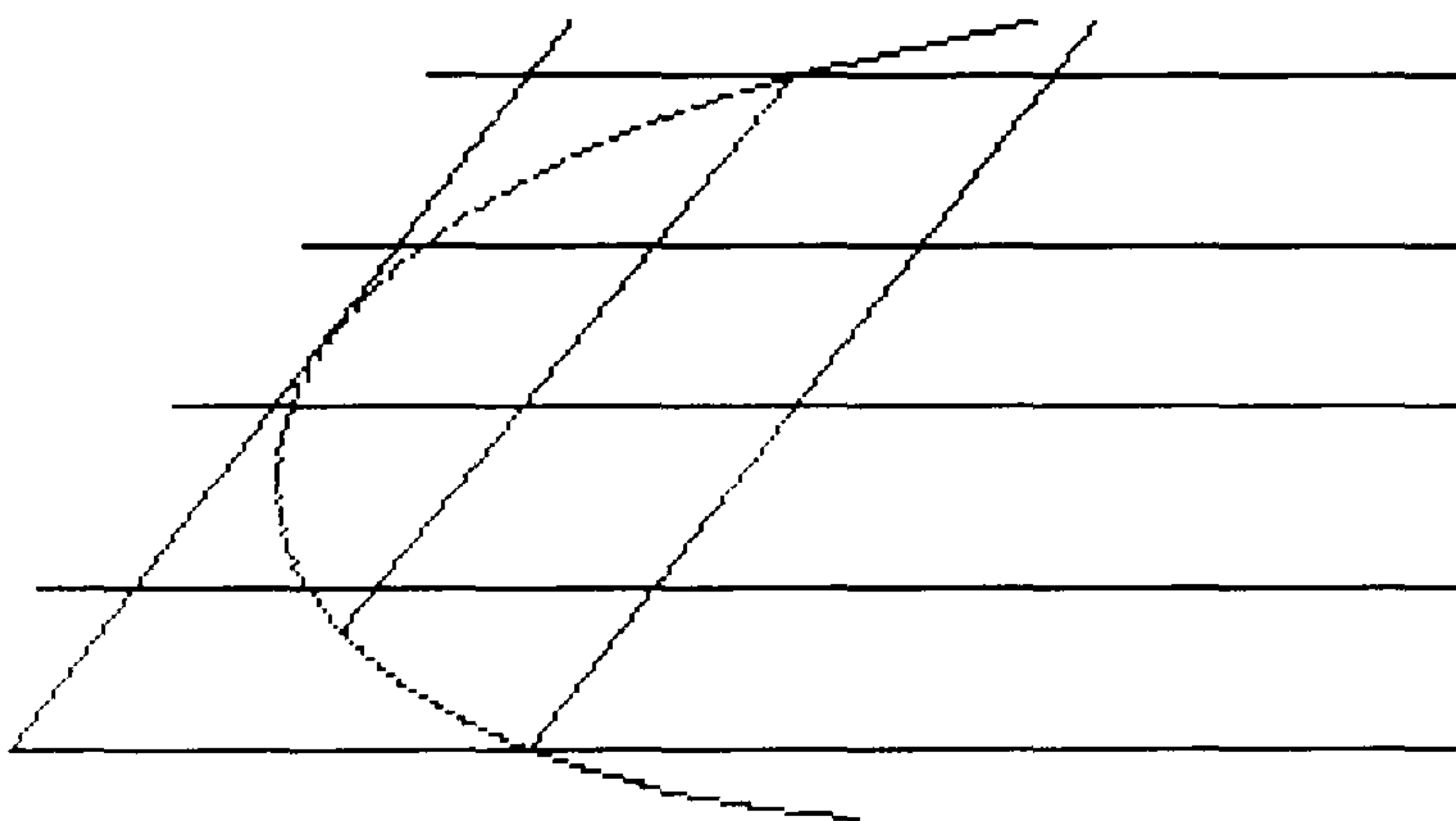


The parabola is one of the boundaries between the ellipse and hyperbola. Suppose ellipse infinitely extended. The circumscribing \odot becomes the axis of y
 $\therefore \perp$ from focus in parabola always meets the tangent in axis of y .



{Find out what becomes of the eccentric anomaly. - (The true anomaly remains).}

The distances of the parabola become $||s$.



The diameter bisects
all chords $||$ to the
tangent as in the
ellipse.

$$\begin{aligned} a(1-e) &= c \\ \frac{b^2}{a^2} &= 1-e^2 \end{aligned} \qquad \frac{b}{a} = 0$$

The axis minor becomes smaller & smaller as compared with the axis major, though the axis major & minor are both greater than in the ellipse.



Appendix C

De Morgan's final letter of resignation*

To the Chairman of the Council of University College.

91 Adelaide Road, November 10, 1866.

Sir,

I feel much sorrow in notifying to the Council that my connection with the College must close at the end of the current session.

For some years the returns of my chair have been so small that, taking into account the time I give, my stay has been an imprudence. I had nevertheless calculated that I might, without too great an injustice to my family, draw upon my capital, if I may use so grand a word, for the means of retaining my post during this and the next session, in the hope of the dawn of better days.

The recent vote of the Council in the case of Mr. Martineau renders it unnecessary for me to settle when I shall leave the College; it proves that the College has left me. I am, as heretofore, strong in the determination not to be overlooked, and not to be controlled in any matter of religious thought, speech, or teaching. The Council has decided that a certain amount of notoriety for advocacy of an unpopular theology is a disqualification. Whether a distinction was intended between the case of a candidate and of an installed Professor I neither know nor care. I assume that such a body as the Council would never entertain this distinction. I concede that A is not B, but I maintain that those who surrender to expediency point A of principle are the men who will surrender point B when the time comes, and who, until the time does come, will be honestly shocked at the prophecy of their future conduct. Adherence to come is discounted to meet the consequence of present departure. The principle of the College has been partially surrendered to expediency; no man can say how much more will be given up, nor when. This I said when the Peene legacy was accepted, and I was laughed at. The acceptance of the conditions of that legacy did not drive me from the College, because, after much deliberation, and not a little help from what I now see to be sophism, my love for the College and the life I led in it barred the way with *De minimis non curat lex*. But I ought to have seen that *minimum* is the first step from *nihil* to *totum*; and when St. Denys, with his head under his arm, had made that

* From Sophia E. De Morgan, *Memoir of Augustus De Morgan*, (London: Longmans, Green, and Co., 1882), 339-345.

first step, I ought to have foreseen the second.** My self-complacency is comforted by observing that there are even now men of experience and thought who not only cannot foresee the third step, but who affirm it will never be made.

Before proceeding to the most delicate part of the subject I make two remarks.

First, in all that I say I am stating the decision of my own court, by which my own course is determined. It is for me alone to weigh evidence, and for me alone to decide. This distinction is often forgotten; such a letter as the present is treated as appeal to those to whom it is addressed, instead of recorded argument in a decided case. Be it remembered that the first sentence of this letter contains the needful; all the rest is partly respect to the body I am addressing, partly evidence of what is thought by a person who has stood by the College for thirty years, and who is likely to represent the opinions of many.

Secondly, I earnestly protest against being supposed to impute to any one, in or out of the Council, the least wilful or conscious impropriety of reasoning or conduct. I mean to give the offence which, in our thin-skinned day, is always taken at plain and uncompromising attack upon alleged wrong proceedings; but I am free of all intention to be personally disrespectful to any of the promoters. I can never forget the cordial co-operation of thirty years.

In the matter of Mr. Martineau, I am aware of the existence of two cross currents. Since the first vote of the Council I have weighed all that I heard, and have for months been satisfied that there has been an objection to his *psychology* as well as to his *religion*: the first is too far removed from atheism to please the philosopher, the second too far removed from orthodoxy to please the priest. No longer neutral between the disputes of Christians, the College is to apply the abandoned principle in another field. The frontier is to be rectified by putting Theism in the place of Unitarianism, and making God an open question, not to be the basis of any teaching on the human mind. And so it is contrived that one and the same victim, offered on the altar of the Janus Bifrons of expediency, shall appease both the priest and the philosopher, while each votary selects the particular head of the deity to which his offering is made.

I proceed to show that (supposing me willing to remain) I am as worthy to be extruded as Mr. Martineau to be excluded.

** Sophia De Morgan added the following footnote: "St. Denys carried his head to Montmartre after his execution. I take the allusion to mean that just as the miracle was complete as soon as the Saint made the first step, so the alienation of the College from its principle was effected at the very earliest departure therefrom."

I have for thirty years, and in my class-room, acted on the principle that positive theism may be made the basis of psychological explanation without violation of any law of the College. When in elucidating mathematical principles it is necessary to speak of our mental organisation as effect of a cause, I have always referred it to an intelligent and disposing Creator. The *nature of things*, the *eternal laws of thought*, and all the ways by which that Creator is put in the dark corner, have been treated by my silence as philosophical absurdities not worthy to have their silly names intruded upon those who are to be trained to think. Were I to remain under the new system, I should hold it a sacred duty and - ah, poor human nature! - a malicious pleasure to extend and intensify all I have hitherto said on this subject.

Again, for more than thirty years I have been as strong a Unitarian as Mr. Martineau. If I have not raised by voice in this matter, and as strongly as Mr. Martineau has done, it is because I have been deeply engaged in other things, because I do not care what unreflecting people think they think, and because I have found that the great bulk of reflecting men of all sects keep their Trinitarianism caged in a creed, and are, in every practical application of religion except pelting Unitarians, as truly Unitarian as Mr. Martineau himself. Were I to continue in this College, under even the ghost of a gag, I should soon be heard (without the walls) on a subject to which I have paid long and close attention. I should soon bring the question to issue whether the installed Professor is or is not a subject for such discussion as has arisen about the candidate for admission.

I hope it will be clear that my absence is as desirable as that of Mr. Martineau. But, for reasons given, I deprecate the supposition of having sacrificed to principle. I have only ceased to sacrifice because the temple has been desecrated. My determination would not be altered by a return to the old principle on the part of the Council. I shall, therefore, not be suspected of any personal motive when I urge the Council to reconsider their suicidal vote, and to re-nail the old flag to the mast.

One point has perhaps been almost overlooked. A teacher of psychology, if he do his duty, expounds all systems of sufficient note, and puts forward the grounds of each. Every one must have his own system, and if one may therefore be suspected of bias, so must another. Mr. Martineau has special reputation as an eclectic teacher. He is noted for ability to prepare students for examination in which the examiners have no bias towards his views. I have heard it remarked, before this discussion, that he crams his pupils with different systems. Such a man does not cram. It means that those of his students who desire no better can cram different systems from his lectures. There is more proof of his competency in this respect than in the case of any of the untried candidates.

Return to the old principle. If the College fall, it will fall with honour. No concession of narrow minds, philosophical or theological, will save it. The enemy will give one sneer more, the friend nine cheers less. Thing'embigot, who says that his son shall not enter the College if Mr. Martineau teach there, never meant to send his son in any case. The late vicar of St. Pancras, then a lessee in Gower Street, found the noise of the playground disagreeable, and sent word that if the nuisance were not abated he should withdraw his patronage; he had been an inveterate opponent. He was left to subtract his negative quantity if he pleased. Let Thing'embigot learn the same rule of algebra.

On the other hand, the enemy of religious disqualification, if the present course be persisted in, must decide whether his son shall be educated under selection carried up to its logical extent in the professed fear of God, or exclusion nibbled at up to compulsion of circumstances in the concealed fear of man as to religion, and another *fear of God* as to philosophy. I should myself be puzzled to make a choice, for if there be a tincture of atheism in the second fear of God, there is a tincture of blasphemy in the first. Of the two different ways of putting man in the place of God, I think the world at large would prefer the first.

My best wishes remain with the College which I leave, but I wish to make myself clearly understood on the question which has been opened. I trust that by return to and future maintenance of the sound principle on which it was founded, in which there is more religion than in all exclusive systems put together, the College will rise into prosperity under the protection, not of the Infinite, not of the Absolute, not of the Unconditioned, not of the Nature of things, not of the chapter of accidents, but of God, the Creator and Father of all mankind.

I am, Sir, with much respect,
Your obedient, humble servant,
A. De Morgan.

Bibliography

A. Published sources

- Address of the Committee of the Society for the Diffusion of Useful Knowledge*, 1846, London: Charles Knight and Co.
- Anderson, Peter John (ed.), 1900, *Roll of Alumni in Arts of the University and King's College of Aberdeen, 1596-1860*, Aberdeen: Printed for the University.
- Appel, Kenneth and Haken, Wolfgang, 1976, 'Every planar map is four colorable', *Bulletin of the American Mathematical Society*, **82**, 711-712.
- Bagehot, Walter, 1879, *Literary Studies*, (ed. Richard Holt Hutton), 2 vols, London: Longmans, Green, and Co.
- Baily, Francis, 1811, *An Account of the Several Life-Assurance Companies established in London*, London: John Richardson.
- Barrington, Emilie Isabel, 1914, *Life of Walter Bagehot*, London: Longmans & Co.
- Bellot, Hugh Hale, 1929, *University College London 1826-1926*, London: University of London Press.
- Biggs, Norman L., Lloyd, E. Keith and Wilson, Robin J., 1976, *Graph Theory 1736-1936*, Oxford: Clarendon Press.
- Bland, Miles, 1812, *Algebraical Problems, producing simple and quadratic equations, with their solutions*, Cambridge: J. Smith.
- Boylan, Henry, 1988, *A Dictionary of Irish Biography*, 2nd edition, Dublin: Gill and Macmillan.
- Bridge, Bewick, 1815, *An Elementary Treatise on Algebra*, London: T. Cadell & W. Davies.
- Brock, William H., 1975, 'Geometry and the Universities: Euclid and His Modern Rivals 1860-1901', *History of Education*, **4**, 21-35.
- and MacLeod, Roy M. (eds.), 1980, *Natural Knowledge in Social Context: The Journal of Thomas Archer Hirst, F.R.S.*, London: Mansell.
- Brooke, Charles, 1829, *A Synopsis of the Principal Formulæ and Results of Pure Mathematics*, Cambridge: J. and J. J. Deighton.
- Brown, Joyce (ed.), 1985, *A Hundred Years of Civil Engineering at South Kensington*, London: Civil Engineering Department, Imperial College.
- Buchanan-Dunlop, Henry Donald (ed.), [1895], *Records of the Royal Military Academy 1741-1892*, Woolwich: F. J. Cattermole.

- Buck, John, 1823, *A New, General, and Algebraical Solution of the Higher Orders of Equations: with solutions of equations, to the tenth degree inclusive*, London: Carpenter and Son.
- Burns, Cecil Delisle, 1924, *A Short History of Birkbeck College*, London: University of London Press.
- Cajori, Florian, 1910, 'Attempts Made during the Eighteenth and Nineteenth Centuries to Reform the Teaching of Geometry', *American Mathematical Monthly*, **17**, 181-201.
- Calendar of King's College, London, for 1848-9*, London: John W. Parker, 1848.
- Cassels, J. W. S., 1979, 'The Spitalfields Mathematical Society', *Bulletin of the London Mathematical Society*, **11**, 241-258.
- Collingwood, Edward F., 1966, 'A century of the London Mathematical Society', *Journal of the London Mathematical Society*, **41**, 577-594.
- De Morgan, Augustus, 1872, *A Budget of Paradoxes*, London: Longmans, Green, and Co.
- 1836, *The Connexion of Number and Magnitude*, London: Taylor and Walton.
- 1842, *The Differential and Integral Calculus*, London: SDUK.
- 1853, *The Elements of Arithmetic*, 5th edition, London: Taylor, Walton and Maberly.
- 1847, *Formal Logic*, London: Taylor and Walton.
- 1836, 'Maskelyne', in *Gallery of Portraits: with Memoirs*, London: Charles Knight and Co., **6**, 20-24.
- 1833, 'A new method to reduce the apparent distance of the moon from a star to the true distance', *Memoirs of the Royal Astronomical Society*, **5**, 251-2.
- 1865, Obituary notice of Benjamin Gompertz, *The Athenæum*, No.1969, 22 July 1865, 117.
- 1855, Obituary notice of Richard Sheepshanks, *Examiner*, 8 Sept. 1855, 562-3.
- 1852, 'On indirect demonstration', *Philosophical Magazine*, (4), **3**, 435-438.
- 1831, 'On mathematical instruction', *Quarterly Journal of Education*, **1**, 264-79.
- 1833, 'On teaching arithmetic', *Quarterly Journal of Education*, **5**, 1-16.
- 1848, 'On the effects of competitory examinations, employed as instruments in education', *The Educational Times*, 1 Dec. 1848, 56-59.

- 1833, 'On the method of teaching fractional arithmetic', *Quarterly Journal of Education*, **5**, 209-22.
- 1833, 'On the method of teaching geometry, part 2', *Quarterly Journal of Education*, **6**, 237-51.
- 1833, 'On the method of teaching the elements of geometry, part 1', *Quarterly Journal of Education*, **6**, 35-49.
- 1831, *On the Study and Difficulties of Mathematics*, London: SDUK.
- 1865, 'On the summation of divergent series', *Journal of the Institute of Actuaries and Assurance Magazine*, **12**, 245-252.
- 1966, *On the Syllogism, and other logical writings*, (ed. Peter Heath), London: Routledge and Kegan Paul.
- 1868, 'Some Account of James Dodson F.R.S.', *Journal of the Institute of Actuaries and Assurance Magazine*, **14**, 341-364.
- 1848, *Speech of Professor De Morgan, delivered at University College, London, Friday, August 4th, 1848, on occasion of the Annual Distribution of Prizes to the Pupils in the Junior School*, London: Richard and John E. Taylor.
- 1865, 'Speech of Professor De Morgan, President, At the First Meeting of the Society, January 16th, 1865', *Proceedings of the London Mathematical Society*, (1) **1**, 1-9.
- 1837, *Thoughts suggested by the establishment of the University of London: An introductory lecture, delivered at the opening of the Faculty of Arts, in University College, Oct. 16, 1837*, London: Taylor and Walton.
- 1849, *Trigonometry and Double Algebra*, London: Taylor, Walton, and Maberly.
- 1843, 'Wrangler', *Penny Cyclopædia*, London: Charles Knight and Co., **27**, 580.
- De Morgan, Mary A., 1895, *Threescore Years and Ten: Reminiscences of the late Sophia Elizabeth De Morgan*, London: Richard Bentley and Son.
- De Morgan, Sophia Elizabeth, 1882, *Memoir of Augustus De Morgan*, London: Longmans, Green, & Co.
- Dodson, James, 1742, *The Anti-Logarithmic Canon*, London: Printed for James Dodson at the Hand and Pen in Warwick Lane; and John Wilcox, at Virgil's Head, opposite the New Church in the Strand.
- 1747-55, *The Mathematical Repository*, 3 vols., London: printed for J. Nourse.

- Domb, Cyril, 1980, 'James Clerk Maxwell in London 1860-1865', *Notes and Records of the Royal Society*, **35**, 67-103.
- Dreyer, John L. E. and Turner, Herbert H. (eds.), 1923, *History of the Royal Astronomical Society 1820-1920*, London: Royal Astronomical Society.
- Drummond, James and Upton, Charles Barnes, 1902, *The Life and Letters of James Martineau*, 2 vols, London: James Nisbet and Co.
- Enros, Philip C., 1983, 'The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics', *Historia Mathematica*, **10**, 24-47.
- Feuer, Lewis S., 1984, 'America's First Jewish Professor: James Joseph Sylvester at the University of Virginia', *American Jewish Archives*, **36**, 151-201.
- Filon, Louis N. G., 1929, Obituary Notice of M. J. M. Hill, *Journal of the London Mathematical Society*, **4**, 313-318.
- Fitch, Joshua G. and Garnett, William, 1911, 'Polytechnic', *Encyclopædia Britannica*, 11th edition, Cambridge: Cambridge University Press.
- Foden, Francis E., 1970, *Philip Magnus: Victorian Educational Pioneer*, London: Vallentine, Mitchell.
- Forsyth, Andrew Russell, 1928, Obituary Notice of William Burnside, *Journal of the London Mathematical Society*, **3**, 64-80.
- Foster, Joseph, 1888, *Alumni Oxonienses 1715-1886*, 4 vols., London: Joseph Foster.
- Fourier, Jean-Baptiste Joseph, 1831, *Analyse des équations déterminées*, Paris: Firmin Didot Frères.
- Gardner, J. Helen and Wilson, Robin J., 1993, 'Thomas Archer Hirst - Mathematician Xtravagant' I-VI, *American Mathematical Monthly*, **100**, 435-441, 531-538, 619-625, 723-731, 827-834, 907-915.
- Garratt, Geoffrey T., 1935, *Lord Brougham*, London: Macmillan and Co.
- Gillispie, Charles C. (ed.), 1970, *Dictionary of Scientific Biography*, 16 vols, New York: Scribner's.
- Glaisher, James W. L., 1886, 'The Mathematical Tripos', *Proceedings of the London Mathematical Society*, (1), **18**, 4-38.
- 1926, 'Notes on the early history of the Society', *Journal of the London Mathematical Society*, **1**, 51-64.
- Grattan-Guinness, Ivor, 1990, *Convolution in French Mathematics, 1800-1840*, 3 vols., Basel: Birkhäuser Verlag.
- 1970, *The development of the foundations of mathematical analysis from Euler to Riemann*, Cambridge, Mass: MIT Press.
- Graves, Robert Perceval, 1882-89, *Life of Sir William Rowan Hamilton*, 3 vols., Dublin: Hodges, Figgis, & Co.

- Grobel, Monica C., 1932, *The Society for the Diffusion of Useful Knowledge, 1826-1846, and its relation to adult education in the first half of the 19th century*, University of London Ph.D. Thesis.
- Guicciardini, Niccolò, 1989, *The Development of Newtonian Calculus in Britain 1700-1800*, Cambridge: Cambridge University Press.
- Guthrie, Frederick, 1880, 'Note on the colouring of maps', *Proceedings of the Royal Society of Edinburgh*, **10**, 727-728.
- Hall, A. Rupert, 1969, *The Cambridge Philosophical Society. A History, 1819-1969*, Cambridge: Cambridge Philosophical Society.
- 1982, *Science for Industry: A Short History of the Imperial College of Science and Technology and Its Antecedents*, London: Imperial College.
- Harte, Negley, 1986, *The University of London 1836-1986*, London: Athlone Press.
- and North, John, 1991, *The World of UCL 1828-1990*, London: University College London.
- Hearnshaw, Fossey J. C., 1929, *The Centenary History of King's College London 1828-1928*, London: G. G. Harrap & Co.
- Heawood, Percy John, 1890, 'Map-colour theorem', *Quarterly Journal of Pure and Applied Mathematics*, **24**, 332-338.
- Henrici, Olaus, 1879, *Elementary Geometry. Congruent Figures*, London: Longmans, Green, and Co.
- Herschel, John, 1820, *A Collection of Examples of the Applications of the Calculus of Finite Differences*, Cambridge: J. Deighton and Sons.
- 1856, *Memoir of Francis Baily*, in *Journal of a Tour in Unsettled Parts of North America in 1796 & 1797, by the late Francis Baily, F.R.S.*, London: Baily Brothers, 1-69.
- Hill, M. J. M., 1918, Obituary notice of Olaus Henrici, *Proceedings of the London Mathematical Society*, (2), **17**, xlii-xlix.
- Hirst, Thomas Archer, 1861, 'On ripples and their relation to the velocities of currents', *Philosophical Magazine*, **21**, 188-198.
- Hoskin, Michael, 1989, 'Astronomers at War: South v. Sheepshanks', *Journal for the History of Astronomy*, **20**, 175-212.
- Howson, A. Geoffrey, 1982, *A History of Mathematics Education in England*, Cambridge: Cambridge University Press.
- Hutton, Charles, 1837, *A Course of Mathematics*, 11th edition, (ed. Olinthus Gregory), 2 vols., London: Longman, Rees & Co.
- 1815, *A Philosophical and Mathematical Dictionary*, 2 vols., London: F.C. & J. Rivington.

- 1785, *Mathematical Tables*, London: G. G. J. & J. Robinson, and R. Baldwin.
- Introductory Lectures Delivered at Queen's College, London*, London: John W. Parker, 1849.
- Jevons, Harriet Ann (ed.), 1886, *Letters and Journal of W. Stanley Jevons*, London: Macmillan & Co.
- Jevons, William Stanley, 1910, 'De Morgan', *Encyclopædia Britannica*, 11th edition, Cambridge: Cambridge University Press.
- Kempe, Alfred Bray, 1879, 'On the geographical problem of the four colours', *American Journal of Mathematics*, **2**, 193-200.
- Ker, William P. (ed.), 1898, *Notes and Materials for the History of University College, London. Faculties of Arts and Science*, London: H. K. Lewis.
- Kilmister, Clive W., 1986, 'The Teaching of Mathematics in the University of London', *Bulletin of the London Mathematical Society*, **18**, 321-337.
- Knight, Charles, 1864-65, *Passages of a working life during half a century*, 3 vols., London: Bradbury & Evans.
- Knight, Frida, 1971, *University Rebel: The Life of William Frend 1757-1841*, London: Gollancz.
- Lardner, Dionysius, 1828, *A Discourse on the Advantages of Natural Philosophy and Astronomy, as part of a general and professional education. Being an introductory lecture delivered...on the 28th October, 1828*, London: John Taylor.
- Larmor, Joseph, 1915, Obituary Notice of Morgan William Crofton, *Proceedings of the London Mathematical Society*, (2) **14**, xxix-xxx.
- Lee, Sidney (ed.), 1901, *Dictionary of National Biography*, First Supplement, 3 vols., London: Smith, Elder, and Co.
- 1912, *Dictionary of National Biography 1901-1911*, London: Oxford University Press.
- and Stephen, Leslie (eds.), 1885-1900, *Dictionary of National Biography*, 63 vols., London: Smith, Elder, and Co.
- Lyell, Charles, 1881, *Life, Letters and Journals of Sir Charles Lyell, Bart...* (Edited by Mrs. Lyell), 2 vols., London: John Murray.
- Lyell, Katharine M. (ed.), 1890, *Memoir of Leonard Horner*, 2 vols., London: Women's Printing Society Ltd.
- MacFarlane, Alexander, 1916, *Lectures on Ten British Mathematicians of the Nineteenth Century*, London: Chapman & Hall.
- MacMahon, Percy A., 1898, Obituary Notice of James Joseph Sylvester, *Proceedings of the Royal Society*, **63**, ix-xxv.

- Magnello, M. Eileen, 1996, 'Karl Pearson's Gresham lectures: W. F. R. Weldon, speciation and the origins of Pearsonian statistics', *British Journal for the History of Science*, **29**, 43-63.
- Maty, Matthew, [1756], *Mémoire sur la vie et sur les écrits de Mr. A. de Moivre*, La Haye: H. Scheurleer.
- May, Kenneth O., 1965, 'The origin of the four-color conjecture', *Isis*, **56**, 346-348.
- Mayor, John E. B., 1884, *In Memoriam: Isaac Todhunter*, Cambridge: Macmillan and Bowes.
- Memoir of Sir Francis Henry Goldsmid*, 2nd edition, London: Kegan Paul, Trench, and Co., 1882.
- Merrill, Daniel D., 1990, *Augustus De Morgan and the logic of relations*, Dordrecht: Kluwer Academic.
- Morrell, Jack and Thackray, Arnold, 1981, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science*, Oxford: Clarendon Press.
- Moseley, Henry, 1850, 'On the Dynamical Stability and on the Oscillations of Floating Bodies', *Philosophical Transactions of the Royal Society*, **140**, 609-643.
- Neuman, B. P., 1920, 'Gower Street in the 'Seventies'', *The Nineteenth Century and After*, **87**, 293-301.
- Nichols, John, 1812-15, *Literary Anecdotes of the Eighteenth Century*, 9 vols., London: Nichols, Son, and Bentley.
- Notes on the History of University College, London, with a Record of the Session 1886-7. Being the first volume of The University College Gazette*, London: University College Society, 1888.
- Orme, Temple, 1892, *University College School, London. Alphabetical and Chronological Register for 1831-1891*, London: H. Walton Lawrence.
- Panteki, Maria, 1992, *Relationships between algebra, differential equations and logic in England: 1800-1860*, C.N.A.A. Ph.D. Thesis.
- Parshall, Karen H. and Rowe, David E., 1994, *The Emergence of the American Mathematical Research Community 1876-1900: J. J. Sylvester, Felix Klein, and E. H. Moore*, Providence: AMS, and London: LMS.
- Pattison, F. L. M., 1987, *Granville Sharp Pattison. Anatomist and Antagonist 1791-1851*, Edinburgh: Canongate.
- Pattison, Granville Sharp, 1831, *Professor Pattison's statement of the facts of his connexion with the University of London*, London: Longman, Rees, Orme, Brown, and Green.
- Perry, John (ed.), 1902, *British Association Meeting at Glasgow, 1901: Discussion on the Teaching of Mathematics*, London: Macmillan and Co.

- Price, Michael H., 1994, *Mathematics for the Multitude? A History of the Mathematical Association*, Leicester: The Mathematical Association.
- Pycior, Helena M., 1983, 'Augustus De Morgan's Algebraic Work: The Three Stages', *Isis*, **74**, 211-226.
- Raimbach, Michael T. S. (ed.), 1843, *Memoirs and Recollections of Abraham Raimbach*, London: F. Schoebel.
- Raleigh, Walter, 1917, *The Faith of England. An Address to the Union Society of University College, London, delivered March 22, 1917*, Oxford: Clarendon Press.
- Ranyard, Arthur Cowper, 1872, Obituary notice of Augustus De Morgan, *Monthly Notices of the Royal Astronomical Society*, **32**, 112-118.
- Rice, Adrian, 1996, 'Augustus De Morgan: historian of science', *History of Science*, **34**, 201-240.
- 1996, 'Mathematics in the metropolis: a survey of Victorian London', *Historia Mathematica*, **23**, 376-417.
- , Wilson, Robin J. and Gardner, J. Helen, 1995, 'From Student Club to National Society: The Founding of the London Mathematical Society in 1865', *Historia Mathematica*, **22**, 402-421.
- Richards, Joan L., 1987, 'Augustus De Morgan, the history of mathematics, and the foundations of algebra', *Isis*, **78**, 7-30.
- 1988, *Mathematical Visions: The Pursuit of Geometry in Victorian England*, Boston: Academic Press.
- Roscoe, Henry Enfield, 1906, *The Life and Experiences of Sir Henry Enfield Roscoe*, London: Macmillan & Co.
- Rouse Ball, Walter William, 1915, 'Augustus De Morgan', *The Mathematical Gazette*, **8**, 42-45.
- 1889, *A History of the Study of Mathematics at Cambridge*, Cambridge: Cambridge University Press.
- and Venn, John A. (eds.), 1911, *Admissions to Trinity College, Cambridge*, 5 vols., London: Macmillan and Co.
- The Royal Charter of the Imperial College of Science and Technology: Jubilee 1907-1957*, London: Edson, 1957.
- Sadler, Thomas (ed.), 1869, *Diary, Reminiscences, and Correspondence of Henry Crabb Robinson*, 3 vols, London: Macmillan and Co.
- Salmon, George, 1847, *A Treatise on Conic Sections*, Dublin: Hodges and Smith.
- A Short History of the City and Guilds of London Institute*, London: City and Guilds of London Institute, 1896.

- Smith, Gordon C., 1982, *The Boole-De Morgan Correspondence 1842-1864*, Oxford: Clarendon Press.
- Society for the Diffusion of Useful Knowledge* [Prospectus], [1826], London: William Clowes.
- Sonnenschein, Adolf and Nesbitt, Henry Arthur, 1870, *The Science and Art of Arithmetic for the Use of Schools*, Parts II and III, London: Whittaker & Co.
- Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, London: B. Fellowes, 1833.
- Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, London: B. Fellowes, 1834.
- Statement of the Arrangements for Conducting the Various Departments of King's College, London...*, London: B. Fellowes, 1838.
- Stein, Dorothy, 1985, *Ada. A Life and a Legacy*, Cambridge, Mass: MIT Press.
- Stephen, Leslie and Pollock, Frederick (eds.), 1879, *Lectures and Essays. By the late William Kingdon Clifford*, 2 vols, London: Macmillan and Co.
- Stirling, Anna M. W., 1922, *William De Morgan and his Wife*, London: Thornton Butterworth Ltd.
- Sylvester, James Joseph, 1865, 'An elementary proof & generalization of Sir I. Newton's hitherto undemonstrated rule for the discovery of imaginary roots', *Proceedings of the London Mathematical Society*, (1), **1**, No.II.
- 1840, 'On Derivation of Coexistence, Part II. Being the theory of simultaneous simple homogeneous equations', *Philosophical Magazine*, (3), **16**, 37-43.
- 1870, 'Presidential Address: Mathematics and Physics Section', *Report of the Thirty-ninth Meeting of the B.A.A.S. held at Exeter in August, 1869*, London: John Murray, 1-9.
- Tait, Peter Guthrie, 1880, 'Note on a theorem in the geometry of position', *Transactions of the Royal Society of Edinburgh*, **29**, 657-660.
- Thynne, William, 1849, *The Theory of Algebraic Equations: a chapter of elementary algebra*, Cambridge: J. & J. J. Deighton.
- Todhunter, Isaac, 1858, *Algebra for the use of colleges and schools*, Cambridge: Macmillan and Co.
- 1876, *William Whewell...An Account of his Writings*, London: Macmillan and Co.
- Tolstoy, Ivan, 1981, *James Clerk Maxwell: A Biography*, Edinburgh: Canongate.
- Toole, Betty A., 1992, *Ada: the enchantress of numbers: a selection from the letters of Lord Byron's daughter and her description of the first computer*, Mill Valley, California: Strawberry Press.

- Tuke, Margaret J., 1939, *A History of Bedford College for Women 1849-1937*, London: Oxford University Press.
- Usher, H. J. K., Black-Hawkins, C. D. and Carrick, G. J., 1980, *An Angel Without Wings: The History of University College School 1830-1980*, London: University College School.
- Venn, John A., 1940-54, *Alumni Cantabrigienses*, Part 2, 6 vols., Cambridge: Cambridge University Press.
- Webb, Alfred, 1878, *A Compendium of Irish Biography*, Dublin: M. H. Gill and Son.
- Wesley, W. H., 1895, 'Arthur Cowper Ranyard and his work', *Knowledge*, 1 February 1895, 25-27.
- Wilson, S. Gordon, 1923, *The University of London and Its Colleges*, London: University Tutorial Press.
- 'Woolwich Royal Military Academy and its Mathematics', *Wade's London Review*, No. 9, June 1845, 639-60.
- Wordsworth, Christopher, 1877, *Scholae Academicæ; Some Account of Studies at the English Universities in the Eighteenth Century*, Cambridge: Deighton, Bell, and Co.
- Yates, R. C., 1937, 'Sylvester at the University of Virginia', *American Mathematical Monthly*, **44**, 194-201.

B. Manuscript sources

I. University College London: Manuscripts and Rare Books Room

i) College Correspondence

- William Sankey to Leonard Horner, 22 May 1827.
- No. 407, John Herschel to Henry Brougham, 1 July 1827.
- William Ritchie to Leonard Horner, 28 July 1827.
- Thomas Hall to Henry Brougham, 5 Nov. 1827.
- John Herapath to Henry Brougham, 19 Nov. 1827.
- No. 404, Olinthus Gregory to Leonard Horner, 19 Dec. 1827.
- Augustus De Morgan to Leonard Horner, 22 Dec. 1827.
- George Biddell Airy to Council, 7 Jan. 1828.
- John Philips Higman to Council, 12 Jan. 1828.
- Henry Coddington to Council, 14 Jan. 1828.
- Henry Parr Hamilton to Council, 30 Jan. 1828.

Thomas Hall to Henry Brougham, 30 Jan. 1828.
 William Whewell to Leonard Horner, 31 Jan. 1828.
 John Philips Higman to George Birkbeck, 1 Feb. 1828.
 Charles Myers to Leonard Horner, 4 Feb. 1828.
 Frederick Leicester to Leonard Horner, 14 Feb. 1828.
 No. 765, Olinthus Gregory to Leonard Horner, 14 Feb. 1828.
 William Moseley to Leonard Horner, 18 Feb. 1828.
 No. 972, Professors' Memorial, 13 May 1828.
 No. 840, Thomas Hewitt Key to Council, [July 1828].
 No. 702, Augustus De Morgan to Thomas Coates, 11 Oct. 1828.
 No. P167, Professor's Memorial signed by Key, Long and De Morgan, [Nov. 1828].
 No. 1614, Letter from E. J. Sylvester, 9 Feb. [1829].
 No. 1615, Letter from E. J. Sylvester, 25 Feb. 1829.
 No. 1177, Augustus De Morgan to Thomas Coates, 3 July 1829.
 No. P106, Augustus De Morgan to Leonard Horner, 12 March 1830.
 No. 3350d, Leonard Horner to Augustus De Morgan, 12 March 1830.
 No. P107, Augustus De Morgan to Leonard Horner, 13 March 1830.
 No. 3350d, Professors' Memorial, 25 March 1830.
 John Walker to Leonard Horner, 17 May 1830.
 No. 3350f, Professors' Memorial, [20 May 1830].
 No. P113, Augustus De Morgan to Leonard Horner, 6 July 1830.
 No. 2470, Augustus De Morgan to the Chairman of the Council, 9 July 1831.
 No. 2173, John Radford Young to Council, 15 Aug. 1831.
 No. 2203, Wilton George Turner to Council, 16 August 1831.
 No. 2174, Edward Turner to Council, 17 Aug. 1831.
 No. 2186, John Buck to Thomas Coates, 5 Sept. 1831.
 No. 2187, William Thynne to Council, 9 Sept. 1831.
 No. 2189, Eneas McIntyre to Thomas Coates, 11 Sept. 1831.
 No. 2194, George Laing to Thomas Coates, 13 Sept. 1831.
 No. 2205, Olinthus Gregory to Thomas Coates, 19 Sept. 1831.
 No. 2248, Guinibert Debac to Council, [26 Sept. 1831].
 No. 2254, George James Pelly White to Council, [4 Oct. 1831].
 No. 2255, Mathematical course outline by G. J. P. White, 17 Oct. 1831.
 No. 2241, Michael Raimbach to Thomas Coates, [18 Oct. 1831].
 No. 2242, G. J. P. White to Thomas Coates, 21 Oct. 1831.
 No. 2783, G. J. P. White to Thomas Coates, 13 Nov. [1832].
 No. 2865, G. J. P. White to Thomas Coates, 4 Feb. 1833.

No. 4148, Wilton George Turner to Council, 11 Jan. 1834.

No. 3260, Report of the Committee appointed to examine the testimonials of the Candidates for the Chair of Mineralogy, [24 Jan. 1834].

No. 3495, Key, Malden and White to Council, 25 July [1835].

No. 3748, Letter addressed: "H. Davis Esq. London University, if absent to the Head Master or any other resident member, *important to be opened immediately*", 29 Sept. 1836.

No. 3763, Thomas Hewitt Key to Charles C. Atkinson, 7 Oct. 1836.

No. 3765, Philip Kelland to Thomas Coates, 8 Oct. [1836].

No. 3768, Augustus De Morgan to Charles C. Atkinson, 10 Oct. 1836.

No. 3779, Augustus De Morgan to Charles C. Atkinson, 19 October 1836.

No. 4488, Report by C. C. Atkinson on the Flaherty bequest, [1836].

No. 4109, C. Duncan to Robert Liston, 15 Sept. [1837].

No. AM/7, Committee Report on the appointment to the chair of natural philosophy, 18 Nov. 1837.

No. 4266, Petition to Senate from James Baldwin Brown and Colman O'Loghlen, [22 March 1838].

Testimonial from Augustus De Morgan on behalf of J. J. Sylvester, [May 1841].

James Joseph Sylvester to Charles C. Atkinson, 17 Aug. 1841.

Richard Potter to Council, 7 Oct. 1841.

Richard Potter to Council, 1 Nov. 1842.

Philip Kelland to Charles Atkinson, 17 March 1843.

Charles Brooke to Council, 15 May 1843.

Student memorandum to Charles Atkinson, 13 Nov. 1843.

Augustus De Morgan to Charles Atkinson, 16 Nov. 1843.

Charles Brooke to Council, 18 Nov. 1843.

No. AM/33, Report on the State of the Class of Natural Philosophy, [25 Nov. 1843].

Charles Brooke to Council, 25 Nov. 1843.

Charles James Hargreave to Charles C. Atkinson, 18 Dec. 1843.

Philip Kelland to Charles Atkinson, 20 May 1844.

Richard Potter to Charles Atkinson, 25 June 1844.

No. AM/70, Report of the Committee appointed to consider Mr Waley's application, [June 1854].

No. AM/103, Report on the Chairs of Natural Philosophy, 1865.

Thomas Archer Hirst to Council, 7 April 1870.

Benjamin Moore to John Robson, 22 Aug. 1870.

Benjamin Moore to John Robson, 1 Sept. 1870.
 George Grote to John Robson, 7 Sept. 1870.
 George Grote to John Robson, 12 Sept. 1870.
 Benjamin Moore to John Robson, 24 Sept. 1870.
 George Grote to John Robson, 12 Oct. 1870.
 No. AM/C/57(ii), Report of Committee on the applications
 for the Chair of Pure Mathematics, July 1880.
 No. AM/C/141, Report on the Applications for the Chair of
 Mathematics at University College London, 7 March 1884.
 No. AM/C/146, Report of the Faculty of Science adopted by
 the Senate of University College, May 7 1884.
 Edward J. Routh to Council, 24 May 1884.
 William Burnside to Council, 24 May 1884.
 Karl Pearson to Council, 26 May [1884].
 No. AM/D/199, M. J. M. Hill to Council, 1 Aug. 1902.

ii) Brougham Correspondence

No. 28,608, Olinthus Gregory to Lord Brougham, 3 Dec. 1830.
 No. 20,220, Olinthus Gregory to Lord Brougham, 7 Nov. 1837.
 No. 17,047, James Joseph Sylvester to Lord Brougham, 22 Nov. 1837.
 No. 20,240, James Joseph Sylvester to Lord Brougham, 16 Sept. 1855.
 No. 18,494, Thomas Hewitt Key to Lord Brougham, 25 Nov. 1864.

iii) The Society for the Diffusion of Useful Knowledge Archives

Augustus De Morgan to Thomas Coates, 6 August 1827.
 Augustus De Morgan to Thomas Coates, 15 March 1830.
 John William Lubbock to Thomas Coates, 6 May [1830].
 Augustus De Morgan to Thomas Coates, [July 1833].

iv) London Mathematical Society Papers

Augustus De Morgan to Thomas Archer Hirst, 20 March 1861.
 George Campbell De Morgan and Arthur Cowper Ranyard to
 Thomas Archer Hirst, 10 Oct. 1864.

Henry Mason Bompas to Thomas Archer Hirst, 18 Jan. 1865.
 James Joseph Sylvester to Thomas Archer Hirst, 11 June 1865.
 Arthur Cayley to Thomas Archer Hirst, 15 June 1865.
 James Joseph Sylvester to Thomas Archer Hirst, 15 June 1865.
 Augustus De Morgan to Thomas Archer Hirst, 29 June 1865.
 Augustus De Morgan to Thomas Archer Hirst, 31 July 1866.
 Thomas Archer Hirst to Augustus De Morgan, 2 Aug. 1866.
 Augustus De Morgan to Thomas Archer Hirst, 4 Aug. 1866.
 James Joseph Sylvester to Thomas Archer Hirst, 11 Aug. 1866.
 Arthur Cayley to Thomas Archer Hirst, 21 [Jan. 1867].
 Arthur Cayley to Thomas Archer Hirst, 25 Jan. 1867.
 Augustus De Morgan to Thomas Archer Hirst, 6 Feb. 1868.

v) Other unpublished documents

Benson, James Bourne, 1921, "Some Recollections of University College in the Sixties", Materials for the history of UCL, Mem. 1B/3.
 De Morgan, Augustus, 1828, "An Introductory Lecture delivered at the Opening of the Mathematical Classes in the University of London, Novr. 5th, 1828", MS.ADD.3.
 De Morgan, Augustus, 1827, "Elements of Statics", MS.ADD.27.
 De Morgan, Augustus, 1857, "Memorandums on the Descendants of Captain John De Morgan...", MS. ADD. 7.
 Filon, Louis N. G., 1919, "Notes for the History of the Department of Applied Mathematics", Materials for the history of UCL, Mem. 2A/18.
 Hepburn, John G., 1847, "Lectures on Algebraic Geometry and the Calculus delivered in University College, London, by Prof. A. De Morgan. Session, 1846-1847", MS.ADD.5.
 Hicks, John Power, 1849-51, "Mathematical Tracts by Professor De Morgan, copied from the original Manuscripts in the Library of University College London by John Power Hicks 1849-1851", MS.ADD.6.
 Hill, M. J. M., 1924, "Some Account of the Holders of the Chair of Pure Mathematics from 1828 to the Present Time", Materials for the history of UCL, Mem. 2A/19.

II. University College London: Records Office

Council Minutes.

Education Committee Minutes.
Committee of Management Minutes.
Register of Students.

III. University of London Library: Special Collections

i) Unpublished correspondence

MS 322/5, Thomas Coates to Augustus De Morgan, 24 Feb. 1828.
MS 322/6, Henry Parr Hamilton to Augustus De Morgan, 27 Feb. 1828.
MS 332/7b, Augustus De Morgan to William Frend, 15 March 1828.
MS 322/10, Leonard Horner to Augustus De Morgan, 2 Sept. 1828.
MS 322/11, Augustus De Morgan to Leonard Horner, 26 Oct. 1828.
MS 322/23, Leonard Horner to Dionysius Lardner, 19 Jan. 1830.
MS 322/52, Professors' Memorial, [May 1831].
AL 45/1, Augustus De Morgan to Council, 24 July 1831.
AL 45/2, Thomas Coates to Augustus De Morgan, 27 July 1831.

ii) De Morgan's mathematical notebooks

MS. 775/1-324, Mathematical Tracts (see Appendix A).
MS. 775/328/1, [On the method of examining students], 21 June 1850.
MS. 775/330, "Augustus De Morgan 1822 Redland":
 school exercise book containing mathematical notes.
MS. 775/332, "Differential Calculus": college notebook.
MS. 775/334, "Section 6th and 7th": college notebook.
MS. 775/335, "Section 8th and Deductions from the 7th
 and 8th Sections": college notebook.
MS. 775/338, "Principia. Vol I. Section 10th and 11th.
 September 1824": college notebook.
MS. 775/342, "Astronomy": college notebook.
MS. 775/343, "Integral Calculus": college notebook.

IV. King's College London: Manuscripts Collection

In-Correspondence, M6, Henry Moseley to Council, 8 Dec. [1831].
In-Correspondence, M34, Henry Moseley to the Rev. Dr. Jelf, 5 Jan. 1844.

V. Royal Society Herschel Papers

MS.HS 9.487, John Herschel to T. W. Hornbuckle, [Oct. 1826].
MS.HS 26.62, John Herschel to Henry Kater, 27 June 1827.
MS.HS 4.303, Henry Brougham to John Herschel, 30 June 1827.
MS.HS 4.305, Henry Brougham to John Herschel, [July 1827].
MS.HS 4.306, John Herschel to Henry Brougham, [July 1827].
MS.HS 2.222, John Herschel to Charles Babbage, 9 March 1828.
MS.HS 6.222, Augustus De Morgan to Sir John Herschel, 19 May 1845.
MS.HS 6.358, Augustus De Morgan to Sir John Herschel, 9 Aug. 1862.
MS.HS 6.400, Augustus De Morgan to Sir John Herschel, 18 Oct. 1867.

VI. British Library: Manuscript Collection

Add MS. 37183, f.454, Henry Warburton to Charles Babbage, 20 Feb. 1827.
Add MS 37183, f.463, Dionysius Lardner to Charles Babbage, 27 March [1827].
Add MS. 37184, f.43, George Harvey to Charles Babbage, 24 May 1827.

VII. Royal Astronomical Society Archives

Augustus De Morgan, "Mathematical Biography extracted from the *Gallery of Portraits* by Augustus De Morgan H.O.M.O. P.A.U.C.A.R.U.M. L.I.T.E.R.A.R.U.M. &c &c &c".

VIII. London Mathematical Society, Burlington House

The London Mathematical Society Minute Book, vol. I.

IX. Bodleian Library, Oxford: Department of Western Manuscripts

Lovelace Byron Papers, box 170.

X. Trinity College, Cambridge

Whewell Papers: Add.Ms.a.202¹⁰², De Morgan to William Whewell, 5 Dec. 1845.

C. Printed material relating to University College

Prospectus of the London University, London: Richard Taylor, [1825].

Statement by the Council of the University of London, Explanatory of the Nature and Objects of the Institution, London: Richard Taylor, 1827.

Second Statement by the Council of the University of London, Explanatory of the Plan of Instruction, London: Richard Taylor, 1828.

University of London. Classes for the Session 1828-9, London: Richard Taylor, 1829.

Distribution of the Prizes and of the Certificates of Honours....Session 1828-1829, London: John Taylor, 1829.

University of London. Notice of the Courses of Lectures during the Session 1829-1830, London: Richard Taylor, 1829.

University of London. Annual General Meeting of Proprietors held on Wednesday, 24th February, 1830, London: Richard Taylor, 1830.

A letter to the shareholders and Council of the University of London on the present state of that Institution, London: Thomas Davison, 1830.

University of London. Distribution of the Prizes and of the Certificates of Honours....Session 1829-1830, London: John Taylor, 1830.

University of London. Annual General Meeting of Proprietors held on Wednesday, the 23rd of February, 1831, London: Richard Taylor, 1831.

University of London. Distribution of the Prizes and Certificates of Honours....Session 1830-1831, London: George Woodfall, 1831.

University of London. Session 1831-32, London: Richard Taylor, 1831.

University of London. Wednesday, 29th February, 1832. The Annual General Meeting of Proprietors... London: Richard Taylor, 1832.

University of London. Regulations for the Discipline of the University, London: Richard Taylor, 1832.

University of London. Report of the Council to the Proprietors. February 1833. London: Richard Taylor, 1833.

University of London. Annual General Meeting of Proprietors held on Wednesday, the 27th of February, 1833, London: Richard Taylor, 1833.

University of London. Report of the Council to the Proprietors. 26th February 1834, London: Richard Taylor, 1834.

University of London. Session 1834-35. Faculty of Arts, London: Richard Taylor, 1834.

University of London. Report of the Council to the Proprietors. 25th February 1835, London: Richard Taylor, 1835.

- University of London. Statement of Facts as to Charter*, London, 1835.
- University of London. Address of the Senate to the Council on the proposed establishment of a Metropolitan University*, London: John Taylor, 1835.
- University of London. Special General Meeting of Proprietors. Held on Wednesday, the 2nd of December, 1835*, London: Richard Taylor, 1835.
- University of London. Annual General Meeting of Proprietors. Wednesday, 24th February, 1836*, London: Richard Taylor, 1836.
- University of London. Faculty of Arts. Distribution of the Prizes and Certificates of Honour. Session 1835-36. With the examination papers*. London: Taylor and Walton, 1836.
- University College, London. Proceedings at the General Meeting of Proprietors, 22nd February, 1837*, London: Richard Taylor, 1837.
- University College, London. Proceedings at the Annual General Meeting of Proprietors, 28th February, 1838*, London: Richard Taylor, 1838.
- University College, London. Proceedings at the Annual General Meeting of Proprietors, 27th February 1839*, London: Richard and John E. Taylor, 1839.
- University College, London. Session 1839-40. Faculty of Arts and Laws*, London: Richard and John E. Taylor, 1839.
- University College, London. Proceedings at the Annual General Meeting of Proprietors, 26th February, 1840*, London: Richard and John E. Taylor, 1840.
- University College, London. Proceedings at the Annual General Meeting of Members of the College, 22nd February, 1843*, London: Richard and John E. Taylor, 1843.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1844*, London: Richard and John E. Taylor, 1844.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 26th February, 1845*, London: Richard and John E. Taylor, 1845.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 25th February, 1846*, London: Richard and John E. Taylor, 1846.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 24th February, 1847*, London: Richard and John E. Taylor, 1847.

- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February, 1849*, London: Richard and John E. Taylor, 1849.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 27th February, 1850*, London: Richard and John E. Taylor, 1850.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 26th February, 1851*, London: Richard Taylor, 1851.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1853*, London: Taylor and Francis, 1853.
- The University College London Calendar for the Session 1853-4*, London: Walton and Maberly, 1853.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 22nd February, 1854*, London: Taylor and Francis, 1854.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 28th February 1855*, London: Taylor and Francis, 1855.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 25th February 1857*, London: Taylor and Francis, 1857.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, 23rd February, 1859*, London: Taylor and Francis, 1859.
- The University College, London, Calendar for the Session 1859-60*, London: Walton and Maberly, 1859.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 29th February, 1860*, London: Taylor and Francis, 1860.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 27th February, 1861*, London: Taylor and Francis, 1861.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 25th February, 1863*, London: Taylor and Francis, 1863.

- The University College, London, Calendar for the Session 1864-65*, London: Walton and Maberly, 1864.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1865*, London: Taylor and Francis, 1865.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 28th February 1866*, London: Taylor and Francis, 1866.
- University College, London. Calendar. Session 1866-67*, London: Walton and Maberly, 1866.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 27th February 1867*, London: Taylor and Francis, 1867.
- University College, London. Calendar. Session 1867-68*, London: James Walton, 1867.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 26th February 1868*, London: Taylor and Francis, 1868.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 24th February 1869*, London: Taylor and Francis, 1869.
- University College, London. Calendar. Session 1869-70*, London: James Walton, 1869.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 23rd February 1870*, London: Taylor and Francis, 1870.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 22nd February 1871*, London: Taylor and Francis, 1871.
- University College, London. Proceedings at the Annual General Meeting of the Members of the College, Wednesday, 28th February 1872*, London: Taylor and Francis, 1872.
- University College, London. Calendar. Session 1876-77*, London: Taylor and Francis, 1876.
- University College, London. Calendar. Session 1883-84*, London: Taylor and Francis, 1883.
- University College, London. Calendar. Session 1894-95*, London: Taylor and Francis, 1894.

University College, London. Calendar. Session 1898-99, London: Taylor and Francis, 1898.

University College, London. Report of the Council, financial statements, and other documents to be presented to the Members of the College at the Annual General Meeting on Wednesday, 25th February, 1903, London: Taylor and Francis, 1903.

The following papers by the author have been accepted for publication during the preparation of this thesis:-

1. From Student Club to National Society : The Founding of the London Mathematical Society in 1865 (with Robin J. Wilson & J. Helen Gardner), *Historia Mathematica* **22** (1995), 402-421.
2. Augustus De Morgan : Historian of Science, *History of Science* **34** (1996), 201-240.
3. Augustus De Morgan (1806-1871), *The Mathematical Intelligencer* **18** No.3 (1996), 40-43.
4. Mathematics in the Metropolis : a survey of Victorian London, *Historia Mathematica* **23** (1996), 376-417.
5. Inspiration or Desperation? Augustus De Morgan's appointment to the Chair of Mathematics at London University in 1828, to appear in *British Journal for the History of Science* **30** (1997).
6. Eleven articles to appear in the *New Dictionary of National Biography*, including
Olaus Henrici
Micaiah John Muller Hill
Isaac Todhunter.

All of these works are incorporated in the main text, with the exception of item 2. This is included as an addendum.

AUGUSTUS DE MORGAN : HISTORIAN OF SCIENCE

Adrian Rice

Middlesex University

“Dates are of as much importance to an historian as to an Arab. The Arab, however, has to dry his; the historian’s are as dry as possible from the outset.”

Letter from Augustus De Morgan to William Rowan Hamilton, 16 August 1852.

1. INTRODUCTION

Most historians of mathematics will be acquainted with the name of Augustus De Morgan (1806–71). One of the most respected British mathematicians of the nineteenth century, he wrote on almost every aspect of pure mathematics, contributing to its development in several key areas. His algebra influenced the development of quaternion theory, while in analysis his rule for determining the divergence or convergence of series still bears his name. Most notably, his research into symbolic logic resulted in the invention of the logic of relations and the formulation of the famous De Morgan Laws, now commonly used in set theory. The first Professor of Mathematics at University College London, De Morgan is also credited as the inventor of the term ‘mathematical induction’ and as popularizer of the Four-Colour Problem. Thus, if one searches the index of any book on the history of mathematics, a reference to De Morgan’s mathematics — however brief — is sure to be found.

However, an examination of such books written from the mid-nineteenth to the early twentieth century shows De Morgan in a quite different light. For, in addition to citing his mathematical publications, they also refer extensively to his research in the history of the science; indeed, some works rely on him more as an historian than a mathematician. Yet recent historians of mathematics seem to have made less use of this side of his academic career¹ despite the fact that not only do historical writings occupy one-sixth of his published work,² but the history of mathematics was considered by him as being of very great value to mathematical investigation and learning.

Moreover, the standard of historical research in these papers is remarkably high for one trained not as an historian but as a mathematician. Many received praise from contemporary scholars. George Peacock (1791–1858) called him “the most accurate & learned of all modern writers on the History of Mathematics”,³ while, according to Walter William Rouse Ball (1850–1925), “he was perhaps more deeply read in the philosophy and history of mathematics than any of

his contemporaries”.⁴ This paper aims to give a critical account of his historical writings, to form some conclusion on how these judgements stand up a century later, and to explore why De Morgan became the historian that history forgot.

2. PRECURSORS

In the century or so before De Morgan, the history of mathematics was a subject still in its infancy, especially in Britain,⁵ where superficial contributions such as John Harris’s *Lexicon technicum* (London, 1704) and Edmund Stone’s *New mathematical dictionary* (London, 1726) were typical of the level of historical scholarship at that time. In Germany, Heilbronner’s *Historia matheseos universae* (Leipzig, 1742), while an attempt at a thorough treatment, was muddled and lacked organization. From the mid-eighteenth century, the principal source of historical work of any calibre was France. The *Histoire des mathematiques* (Paris, 1758) of Jean Etienne Montucla (1725–99) was the first full-scale account of the development of mathematical ideas to be both thorough and accurate. The second edition, published in four volumes between 1799 and 1802, covered the subject from the Greeks to the late eighteenth century, and included pure mathematics, optics, mechanics, astronomy, mathematical geography and navigation.⁶

With the increase of awareness of Continental works among British mathematicians, the late eighteenth century saw a rise in the quality of historical accounts produced. Charles Hutton (1737–1823), Professor of Mathematics at the Royal Military Academy in Woolwich and Foreign Secretary of the Royal Society, wrote a bulky *Mathematical and philosophical dictionary* (London, 1796) which contained some well-informed historical articles. To remedy the “superficial and partial way the inquiry has been investigated, even by professed writers on the subject”,⁷ Hutton’s work contained many biographical articles along with his accounts of the various mathematical branches. These included quite lengthy discussions “of the origin and progress of each of these Sciences, as well as of the inventions and improvements by which they have been gradually brought from their first rude beginnings to their present advanced state”.⁸

Hutton also attempted a more dispassionate evaluation of national contributions than previous British historians of mathematics. One of the most partisan of his predecessors had been John Wallis (1616–1703), whose *Treatise of algebra* (London, 1685) sought to give a historical account of the development of algebra up to his own day.⁹ In evaluating Wallis’s work, Hutton remarked that “Wallis has shewn too much partiality to the Algebra of Harriot”¹⁰ when evaluating Vieta. However, when he came to comment on Descartes, Hutton proved little less partial than Wallis, commenting that Descartes had “borrowed his improvements in Algebra from Harriot’s *Artis Analyticae Praxis*”.¹¹ In fact, in his articles concerning the calculus controversy, Hutton could have been writing at the beginning, not the end of, the eighteenth century. His belief — and that of many others before and after him — that “ever since 1684, Leibnitz had

been artfully working the world into an opinion, that he first invented this method"¹² despite the fact that "Newton had discovered his Method of Fluxions many years before the pretensions of Leibnitz",¹³ illustrates how long-lasting were the effects of the priority dispute nearly a century before.

Other historical writing that influenced De Morgan was that of the French astronomer Jean-Baptiste Joseph Delambre (1749–1822). Delambre was also an accomplished historian, although he took to it late in life. His most famous work, the six-volume *Histoire de l'astronomie* (Paris, 1817–27), was a model of historical and scientific research. Indeed, as De Morgan pointed out: "It is not merely a digest of ideas ... but an actual abstract of every work which has exercised the least influence on the progress of the science, whether Greek, Arabian, or modern European. This task by itself would have been abundantly sufficient to secure to its author the reputation of a long life well spent; for he had to wade through the writings of every age and country, and in particular to acquire a knowledge of the mathematical styles of different times, which are sufficiently distinct to render them, we might almost say, sciences of different species."¹⁴

Despite this claim about "every age and country", Delambre gave little consideration to Indian science. This deficiency was recognized when Henry Thomas Colebrooke (1765–1837) undertook his study of the history of mathematics on the subcontinent. The son of Sir George Colebrooke, chairman of the East India Company, Henry Colebrooke lived in India for over thirty years, during which time he became Europe's leading Sanskrit scholar, publishing works on many aspects of Hindu culture including literature, law and science. In his investigation of mathematics, he particularly concentrated on Indian algebra, publishing the first major work on that subject, *Algebra, with arithmetic and mensuration, from the Sanskrit of Bramegupta, and Bhascara, preceded by a dissertation on the state of science as known to the Hindus* (London, 1817). His work greatly encouraged serious European considerations of non-Western mathematics.

However, for a student of mathematics in the early 1820s eager to acquire some knowledge of his subject's history, the situation was far from satisfactory. In Britain, no translation of Montucla or Delambre was ever attempted, nor an alternative history compiled. A sound knowledge of French was thus essential, short of examining the original sources themselves. A further problem, more peculiar to Britain, was that, in the absence of any equivalent to Montucla or Delambre, many minor British mathematicians and natural philosophers went largely unrecorded by Hutton and the other dictionary compilers who tended to concentrate on less obscure figures for their compendia. England was thus open territory for a keen historian of mathematics.

3. DE MORGAN'S HISTORICAL CAREER

After an adequate classical education, in which he received a thorough grounding in Latin, Greek and Hebrew, Augustus De Morgan entered Trinity College,

Cambridge, at the age of sixteen. There, under the influence of tutors such as George Biddell Airy (1801–92), William Whewell (1794–1866) and George Peacock (1791–1858), he developed a life-long love of the study of mathematics. His arrival in Cambridge occurred a decade after the formation of the short-lived, but influential, Analytical Society by Charles Babbage (1792–1871), John Herschel (1792–1871) and George Peacock.¹⁵ Although the Society's main achievement had been the introduction of Continental calculus methods into the Cambridge syllabus, a by-product of this reform was the stimulation of curiosity in the history of the subject. Robert Woodhouse (1773–1827), whose own work had partially anticipated that of the Society, had produced *A treatise on isoperimetrical problems and the calculus of variations* in 1810 which was a well-researched history of its development, while the sole volume of the Society's *Memoirs* of 1813 contained a preface by Babbage and Herschel which served as an excellent summary of the progress of methods on the Continent over the previous three decades.

By the time of De Morgan's residence in Cambridge, the history of not only the calculus but all branches of mathematics was a subject of much interest — albeit extra-curricular — among mathematicians, not least because of the scarcity of works on the subject. John Playfair (1748–1819) contributed an excellent "Dissertation ... exhibiting a general view of the progress of mathematical and physical science since the revival of letters in Europe" to the fourth edition of the *Encyclopaedia britannica*, while the *Encyclopaedia metropolitana* contained an article on "Arithmetic" (nearly three-quarters of which was an historical account) by one of De Morgan's own teachers, Peacock. Written in 1826, this treatise was the most rigorous history of the subject yet attempted, considering its rise not just in Europe but all over the world including accounts of Tibetan, Chinese, Malayan, Persian, Arabic, Hebrew, Celtic, Aztec and Eskimo number systems! Like many others, this article was undertaken because "there does not exist any source of information on this subject which can be deemed trust-worthy and authentic, except in the original authors themselves"¹⁶ — much the same view as Charles Hutton thirty years before.

De Morgan thrived in this intellectual atmosphere. He was by nature a compulsive reader on almost any topic and, when not consuming mathematical books, he would devote his leisure hours to the study of works on philosophy, metaphysics, theology, literature and history. Towards the end of his life he wrote to a friend: "I did with Trinity College library what I afterwards did with my own — I foraged for relaxation."¹⁷ A result of this discursive reading was the development of an almost encyclopaedic knowledge of the history and philosophy of science. His wife recalled that as early as their meeting in 1827, he was already expert on antiquarian science, being "well informed in Eastern astronomy and mythology" and critical of writers on the subject, pointing out "the insufficiency of their theories to account for all that they have tried to explain".¹⁸

De Morgan's keen intellect was anchored to a very strong religious and ethical

conscience. Although born of strict evangelical stock, he quickly developed non-conformist tendencies and refused to declare allegiance to any particular church, retaining a powerful moral sense of right and wrong until the end of his life. This principled stance led to his departure from Cambridge after obtaining his degree in 1827, since further progress at that time was dependent on membership of the Church of England.¹⁹ Fortunately, this period coincided with the foundation of the secular London University (now University College), and in 1828 De Morgan ensured the continuation of his mathematical studies through his appointment as foundation Professor of Mathematics.²⁰

His move to London also saw the beginning of his relationship with the Society for the Diffusion of Useful Knowledge (SDUK), a body which involved many of those connected with the University, including the Whig politician (and later, Lord) Henry Brougham (1778–1868). Founded in 1826, the Society's chief aim was to provide informative, educational, intelligible, but above all, cheap factual information for the improvement of the educated layman. It was through the SDUK and the new University that De Morgan commenced the publication of original books and papers, on various mathematical and related topics, his first book, a translation of Bourdon's *Algebra*, appearing in 1828.

Between 1831 and 1835, the SDUK published a *Quarterly journal of education* to which De Morgan contributed no fewer than thirty-three articles relating to mathematical education. It was in the pages of this journal that his first historical article appeared. Bearing the title "Polytechnic School of Paris", the paper is a very interesting and informed account of "the history and methods of the most celebrated school of instruction for engineers which has ever existed",²¹ from its first proposal by Monge in 1791 to the upheavals of July 1830. Yet although the article is a good account of the School's brief life, the level of research for it could hardly be called profound, the majority of the historical information coming from A. Fourcy's *Histoire de l'Ecole Polytechnique* (Paris, 1828).

De Morgan's first full-scale historical papers began to appear, not long after the demise of the *Quarterly journal*, in the *Companion to the almanac*. This was an annual publication (also sponsored by the SDUK) to which he was to contribute twenty-seven articles in consecutive years from 1831 on various subjects including insurance, astronomy, the calendar and decimal coinage. Articles concerning the history of science formed a third of these contributions, ranging from "Old arguments against the motion of the Earth" to "A short account of some recent discoveries in England and Germany relative to the controversy on the invention of fluxions". All dealt with points not previously considered, all were scrupulously researched and referenced, and most were soon widely cited by fellow historians of science.

In the early to mid-1830s, he wrote twelve potted biographies for Charles Knight's *Gallery of portraits: with memoirs*, but a more substantial undertaking began in 1833 with the launch of the SDUK's *Penny cyclopaedia* to which De

Morgan contributed mathematical and astronomical articles for more than ten years. In all, he wrote well over seven hundred pieces, many of some considerable length, amounting to an estimated one-sixth of all the entries, of which a fair proportion are historical. These are well worth study, especially the biographical articles which excellently illustrate the vast extent of his reading and knowledge of figures as diverse as Roger Bacon, John Collins and Gaspard Monge. A selection of them is given in Table 1. Once again, to acquire an idea of the value of De Morgan's historical articles in the *Penny cyclopaedia*, one has only to look through the entries on scientific figures in the *Dictionary of national biography* to see how often they are cited.

His next major biographical work was a forty-page life of Newton for Knight's *Cabinet portrait gallery of British worthies* in 1846. De Morgan, in common with many of his predecessors and contemporaries, was fascinated by Newton: and this attraction, combined with his instinctive sense of fair play, led to his research into the calculus controversy and the publication of his findings in various journals. By this time, in addition to the *Companion to the almanac*, his historical studies were gracing the pages of the *Philosophical magazine* and the Royal Society's *Philosophical transactions*, bringing them to an even wider audience. His work in this area is concentrated between 1846 and 1856: it was to have a marked effect on the way Newton was perceived by future historians of science.

During the late 1850s, De Morgan published very little in the way of history, concentrating primarily on papers on logical and actuarial matters. This is not to say that his enthusiasm for the subject had weakened. Indeed, there is evidence for his interest widening, his logical works of this period being peppered with footnotes and references concerning the history of logic and philosophy in general.²² In 1857, as a purely recreational exercise, he began to compile a detailed history of his family going as far back as 1694, which, though never intended for publication, reveals a remarkable skill and enjoyment of historical investigation.²³ However, papers on history of science are noticeably absent from the list of De Morgan's publications at this time, the only historical item to be issued being "Notes on the history of the English coinage" in the *Companion to the almanac* of 1856.

Historical publication resumed in 1863 with the start of a series of humorous articles in the *Athenaeum* magazine (for whom he had already been a regular columnist for over twenty years) under the title "A budget of paradoxes". Each article was a review of an obscure work — selected from De Morgan's library (by now extensive) of vintage mathematical books — illustrative of a particularly unusual scientific opinion or system. These he termed 'paradoxes', explaining, "a paradox is something which is apart from general opinion, either in subject matter, method, or conclusion".²⁴ Thus, his paradoxers included "any squarer of the circle, trisector of the angle, duplicator of the cube, constructor of perpetual motion, subverter of gravitation, stagnator of the earth, builder of the

universe, &c.”.²⁵ Needless to say, he was not short of material and the ‘Budget’ series ran for nearly four years.

The years following his retirement from University College in 1867 were plagued by illness and misfortune. The death of his son George in that year and of a daughter, Helena Christiana, three years later, together with the effects of a stroke in 1868, left him dramatically weakened. He still continued to write, extending his “Budget of paradoxes” and collecting further material for yet more work on Newton. His last historical work to appear during his lifetime was published in the *Journal of the Institute of Actuaries* in 1868. Entitled “Some account of James Dodson F.R.S.”, it was a biography of his great-grandfather.²⁶ The author died on 18 March 1871.

A list of De Morgan’s principal historical works is given in Table 1. They cover a wide range of subjects, but five main topics occupied his attention: astronomy; the calculus controversy, and the vindication of Leibniz; Newton and his niece; arithmetic; and bibliography.

4. ASTRONOMY

The bulk of De Morgan’s work on the history of astronomy focuses on the sixteenth and seventeenth centuries and, in particular, on the debate caused by the emergence of the Copernican system in that period. Right from the start, he was anxious to clarify his terminology and avoid the confusions of previous writers on the subject. When referring to the ‘Copernican system’, he emphasised that he meant “the system which actually was promulgated by the man named Copernik”²⁷ “and not the Keplerian, Galilean, Newtonian, Halleian, Laplacian, &c.”.²⁸ He explained: “Our usual popular treatises speak of Copernicus as if, besides himself, he had in him no inconsiderable fraction of Kepler, Galileo, Newton, and Halley”,²⁹ and that, as a result, “we are accustomed to see Copernicus represented as a man so far in advance of his age, that in the main points of his system nothing has been added and nothing subtracted”.³⁰

This led him to a provocative point: “The question whether Copernicus himself was a *Copernican* in the modern sense of the word is not easily settled ... because the author seemed to be speaking *problematically*”³¹ Distinguishing between *mathematical* and *physical* Copernicanism, he concluded that the author of *De revolutionibus*, while certainly the originator of the former, never publicly affirmed his adherence to the stronger physical doctrine. Moreover, De Morgan pointed out the distinctly conservative nature of Copernicus’s mechanics, observing that “modern historians dwell very little on the *Aristotelian* arguments which were urged on the Copernican side of the question, even by Copernicus himself”.³² Nevertheless, De Morgan’s overall evaluation of Copernicus was high, “though lower than the one usually assigned to it”.³³

More valuable than his opinion of Copernicus (however well-informed) are his accounts of the new system’s reception during the decades before the

TABLE 1. De Morgan's principal historical writings.

(a) *Contributions to periodicals*

Indicative Title	Journal	Volume, pages	Year
Polytechnic School of Paris	<i>QJE</i>	i, 57–74	1831
Old arguments against the motion of the Earth	<i>CA</i>	5–20	1836
English mathematical & astronomical writers before 1600	<i>CA</i>	21–44	1837
Progress of the problem of evolution	<i>CA</i>	34–52	1839
Leonardo da Vinci's use of + and –	<i>PM</i>	(3) xx, 135–7	1842
References for the history of mathematical sciences	<i>CA</i>	40–65	1843
On the ecclesiastical calendar	<i>CA</i>	1–36	1845
The earliest trigonometrical canon	<i>MNRAS</i>	vi, 221–8	1845
Dispute between Keill & Leibnitz on invention of fluxions	<i>PTRS</i>	cxxxvi, 107–9	1846
Derivation of the word Theodolite	<i>PM</i>	(3) xxviii, 287–9	1846
Derivation of Tangent and Secant	<i>PM</i>	(3) xxviii, 382–7	1846
On the earliest printed almanacs	<i>CA</i>	1–31	1846
Mathematical bibliography	<i>DR</i>	xxi, 1–37	1846
The opinion of Copernicus on the light of the planets	<i>MNRAS</i>	vii, 290–3	1847
Account of the speculations of Thomas Wright	<i>PM</i>	(3) xxxii, 241–52	1848
Additions made to the 2nd edn. of the <i>Comm. epist.</i>	<i>PM</i>	(3) xxxii, 446–56	1848
On ancient and modern usage in reckoning	<i>CA</i>	5–34	1850
On some points in the history of arithmetic	<i>CA</i>	5–18	1851
On the authorship of the “Account of the Comm. Epist.”	<i>PM</i>	(4) iii, 440–44	1852
On the early history of infinitesimals in England	<i>PM</i>	(4) iv, 321–30	1852
Some recent discoveries relative to the fluxions controversy	<i>CA</i>	5–20	1852
On the difficulty of correct descriptions of books	<i>CA</i>	5–19	1853
Lord Halifax and Mrs Catherine Barton	<i>N&Q</i>	(1) viii, 429–33	1853
Review of Brewster's <i>Memoirs of Sir Isaac Newton</i>	<i>NBR</i>	xxiii, 307–38	1855
Doctrine of the Earth's motion from Copernicus to Galileo	<i>CA</i>	5–25	1855
Lord Halifax and Mrs Catherine Barton	<i>N&Q</i>	(2) ii, 161–3	1856
History of the signs + and –	<i>Ath</i>	no. 1925, 376	1864
On the early history of the signs + and –	<i>TCPS</i>	xi, 203–12	1864
The portrait of Copernicus	<i>GM</i>	(2) i, 804–8	1866
Some account of James Dodson FRS	<i>JIA</i>	xiv, 341–64	1868

- QJE:* *Quarterly journal of education*
CA: *Companion to the almanac*
PM: *Philosophical magazine*
MNRAS: *Monthly notices of the Royal Astronomical Society*
PTRS: *Philosophical transactions of the Royal Society*
DR: *Dublin review*
N&Q: *Notes and queries*
NBR: *North British review*
Ath: *Athenaeum*
TCPS: *Transactions of the Cambridge Philosophical Society*
GM: *Gentlemen's magazine*
JIA: *Journal of the Institute of Actuaries and Assurance Magazine*

(b) *Contributions to Charles Knight's Gallery of portraits: with memoirs*

Title	Volume	Pages	Year
Halley	i	161–8	1833
Laplace	ii	34–39	1833
Lagrange	ii	88–92	1833
Dollond	iii	12–18	1834
Delambre	iv	165–9	1835
Descartes	iv	189–93	1835
W. Herschel	v	105–10	1835
Euler	v	129–33	1835
Harrison	v	153–6	1835
Maskelyne	vi	20–24	1836
Bradley	vi	69–74	1836
Leibnitz	vi	132–6	1836

(c) *Illustrative selection of historical contributions to the Penny cyclopaedia*

Title	Volume	Pages	Year
D'Alembert	i	289–91	1833
Anaxagoras	i	503–4	1833
Anaximander	i	504	1833
Anaximenes	i	504	1833
Apollonius (Pergaeus)	ii	166–7	1834
Archimedes	ii	277–9	1834
Aristarchus	ii	321–2	1834
Bacon, Roger	iii	241–4	1835
Barrow, Isaac	iii	508–9	1835
Berkeley, George (2nd half)	iv	280–1	1835
Bernoulli	iv	314–17	1835
Boyle, Robert	v	297–301	1836
Brahe, Tycho	v	323–7	1836
Briggs, Henry	v	422–3	1836
Campanus, John	vi	201–2	1836
Cocker, Edward	vii	312	1837
Collins, John	vii	351	1837
<i>Commercium epistolicum</i>	vii	399	1837
Copernicus, Nicolaus	vii	498–501	1837
Cotes, Roger	viii	87	1837
Flamsteed, John	x	296–7	1838
Fluxions	x	330–2	1838
Fourier, Joseph	x	389–90	1838
Geometry	xi	151–5	1838
Halley, Edmund	xii	19–21	1838
Herschel, William	xii	175–6	1838
Horrocks, Jeremiah	xii	305	1838
Huyghens, Christian	xii	363–5	1838
Laplace, Pierre Simon	xiii	325–8	1839
Legendre, Adrien Marie	xiii	392–3	1839
Maclaurin, Colin	xiv	250–1	1839
Monge, Gaspard	xv	327–8	1839
Musa, Mohammed Ben	xvi	7	1840
<i>Principia</i>	xix	5–12	1841
Taylor, Brook	xxiv	124–7	1842
Theon, the Elder	xxiv	330–1	1842
Vieta, Francis	xxvi	311–18	1843
Viga Ganita	xxvi	318–25	1843
Wallis, John	xxvii	41–43	1843

(d) *Contributions to William Smith's Dictionary of Greek & Roman biography & mythology*

Title	Volume	Pages	Year
Diophantus	i	1050–1	1844
Eucleides	ii	63–74	1849
Heron	ii	436–8	1849
Hipparchus	ii	476–7	1849
Ptolemaeus, Claudius	iii	569–77	1849
Sosigenes	iii	882–3	1849
Theon	iii	1079–80	1849

(e) *Contribution to Charles Knight's Cabinet portrait gallery of British worthies*

Title	Volume	Pages	Year
Newton	xi	78–117	1846

(f) *Books*

- Arithmetical books from the invention of printing to the present time* (London, 1847)
- A budget of paradoxes* (edited by S. E. De Morgan) (London, 1872)
- Newton: his friend: and his niece* (ed. by S. E. De Morgan & A. C. Ranyard) (London, 1885)

discoveries of Galileo — an area strangely disregarded by previous historians. “In treating of old matters of controversy,” he wrote, “it were to be wished that those who write would quote the very words of the earliest advocates of both sides”.³⁴ De Morgan did so. In two complementary articles, written nearly twenty years apart, he exploited his wide reading to excellent effect by outlining the views of over twenty-five contemporaneous scientists on the new astronomy “to bring some of the arguments of the two parties into contact with the notions our readers may have formed of their relative merits from the popular works most in vogue”.³⁵

The scholars mentioned vary from total opponents of Copernicanism (Christopher Clavius) to partial supporters (William Gilbert) to vigorous champions (Rheticus). But more significantly, they range from notable names such as Peter Ramus, Francis Bacon and Tycho Brahe (“a mathematical Copernican and a physical Ptolemaist”³⁶) to those who are now, as in De Morgan’s day, almost completely unknown. It is not only the discovery of the viewpoints of such obscure philosophers as Thomas Fienus (*fl.* 1619) and Francis Patricius (d. 1597) that makes these articles especially valuable, but in addition, the disclosure of little-known opinions of Robert Recorde, Simon Stevin and Franciscus Vieta on the subject that renders them particularly interesting to the historian of science.³⁷

De Morgan’s own impression of the arguments on both sides was that “before the time of Galileo ... every Copernican was an ingenious theorizer, supporting a system which, though simple and possible, was met by unanswerable and *crucial* arguments, mixed with others derived from pure assumptions common to both parties”.³⁸ Hence the system of Tycho Brahe — who De Morgan believed to be “the strongest of all the admirers of Copernicus”.³⁹ “To us,” he concluded, “the system of Copernicus appears a premature birth: the infant long remained sickly, and would certainly have died if it had not fallen under better management than that of its own parents”.⁴⁰

The earliest convert to the new heliocentrism in England was, according to De Morgan, Robert Recorde (*c.* 1510–58). Making this claim in an article for the *Companion to the almanac* of 1837, De Morgan alleged “that he was at least as early an avowed Copernican as any other Englishman, and very likely before any other”.⁴¹ However, he is forced to acknowledge that, like Copernicus himself, Recorde made no direct declaration of belief, because of “his own implied assertion that he did not think the world ripe for any such doctrine”.⁴² In addition to his Copernicanism, De Morgan also credits Recorde with being the first writer on arithmetic, geometry and astronomy in the English language, as well as introducing algebra to our shores. In Recorde’s *Pathway to knowledge*, he also observed the first use of the word ‘sine’ in an English work.

This article is noteworthy, not only for De Morgan’s discussion of the work of Recorde and other sixteenth-century mathematicians and astronomers such as John Dee and Leonard and Thomas Digges, but for its unprecedented account of ninety-two other practitioners of those sciences in England from 1060 to the close of the sixteenth century. The more renowned figures include Adelard of

Bath, Roger Bacon, Sacrobosco, Duns Scotus, Nicholas Ockham, Roger Swineshead and Geoffrey Chaucer, but they are outweighed by the mass of unknown names that De Morgan had uncovered, many of whom, one would imagine, had scarcely appeared in print before. De Morgan was well aware that, since the early progress of English science was “a part of its history which is as yet altogether unwritten in a connected form”,⁴³ this article, though only a sketch, was of great historical importance.

De Morgan vigorously believed in the importance of acquainting his readers with obscure writers and writings of the past. His motive was twofold. Firstly, for its own sake; and secondly, so that his audience could judge for themselves whether these authors deserved their obscurity, and conversely, whether those more distinguished merited quite so much fame. This conviction is demonstrated again and again in his work on the history of science, a good example being his discovery of the cosmic hypotheses of Thomas Wright of Durham (1711–86), published in 1848.

Wright was a deviser of mathematical instruments who published various works on navigation and astronomy, one of which, quite by chance, found its way into De Morgan’s library. He wrote to Sir John Herschel in 1845: “I have had a book by me for years called *An original theory or new Hypothesis of the Universe* by Thomas Wright of Durham, London 1750 4to.... I always supposed it to be ocular and Elizabethan if you know what that means, and put it among my curiosities of that kind. But, overhauling my limbo to write an article about quiddities, I began to examine this book, and I find it is at great length the true theory of the milky way as a resolvable nebula, with distribution of the Universe into patches of starlight.”⁴⁴

De Morgan realized that Wright’s speculations pre-dated the nebular studies of his great contemporary William Herschel (1738–1822), who won fame almost overnight by his discovery of the planet Uranus in 1781. Wright anticipated discoveries of such a kind, as De Morgan points out: “It is not often, in his day, that we find, as in his works, the planets described as the *known planets*, implying an assumption that there might be more.... His prediction of the ultimate resolution of Saturn’s rings into congeries of small satellites remains to be verified; but it is thought by some to be most probable that such is the truth.”⁴⁵ In order to introduce the public to Wright’s work (then long out of print), De Morgan wrote his account “of a speculation which must take a high rank among those daring and yet sober attempts at prediction of future results, which are, and ought to be, repaid upon success for the contempt with which they are always received on appearance”.⁴⁶ A shorter account of Wright’s *Theory* appears in the *Budget of paradoxes*.⁴⁷

5. THE CALCULUS CONTROVERSY

As we have seen, even as late as the early 1800s the reputation of Leibniz among British scientists was that of a plagiarist who had tried to steal the credit for the invention of the calculus from Newton; and this attitude had not changed in any

significant way by the time De Morgan began his academic career. Likewise, in Britain at least, the virtual deification of Sir Isaac remained largely unchallenged. In De Morgan's words, "it was in Britain the temper of the age ... to take for granted that Newton was human perfection".⁴⁸ It must be remembered that we are firmly within the period when biographers saw their function as one of providing a moral tale as much as objective evaluation. Thus in *The life of Sir Isaac Newton* (London, 1831) by the Scottish physicist Sir David Brewster (1781–1868), abundant praise of "the most exalted genius"⁴⁹ permeated the text.

Predictably, Brewster deviated not one iota from the opinions of his forebears on the priority dispute, ruling that Newton was the inventor and Leibniz the plagiarist. Despite acknowledging that Leibniz's actions during the dispute might be thought no worse than those of Newton and his supporters, Brewster was adamant that "the circumstances of the case will by no means justify such a comparison. The conduct of Newton was at all times dignified and just",⁵⁰ whereas "the conduct of Leibnitz was not marked with the same noble lineaments".⁵¹ In the eyes of David Brewster, Newton's behaviour scarcely needed justification: "he knew his place as a philosopher, and was determined to assert and vindicate his rights."⁵² Yet, by exercising the same prerogatives, Leibniz had "cast a blot upon his name, which all his talents as a philosopher, and all his virtues as a man, will never be able to efface".⁵³

Then, in 1835, came the first English work to dare to throw a different light on Newton's character. Written by the founder of the Royal Astronomical Society, Francis Baily (1774–1844), *An account of the Rev. John Flamsteed* (London, 1835) profoundly shocked the scientific community. Through his discovery of previously unpublished correspondence between the first Astronomer Royal and men such as Abraham Sharp (1651–1742), Edmond Halley (1656–1742) and Newton himself, Baily revealed that Newton had treated Flamsteed unfairly over the publication of the latter's catalogue of stars, even to the extent of deleting all references to Flamsteed's provision of valuable astronomical data in later editions of the *Principia*.⁵⁴ The first blow had been struck. The impact of Baily's huge volume was felt not only because of his audacity in revealing a flaw in Newton's nature, but also by the vast number and range of sources he used to strengthen his case.

As recent authors such as Geoffrey Cantor and Richard Yeo have argued, for scholars such as David Brewster and William Whewell, disturbing revelations about Newton's personality directly impaired their view of Newton as a paragon of national, scientific and religious virtue. This is hardly surprising when one remembers that, in John Gascoigne's words, "one of the most distinctive features of British intellectual life in the eighteenth century, and in much of the nineteenth, was the extent to which science was seen to be allied to the cause of religion".⁵⁵ Stephen Peter Rigaud (1774–1839), Savilian Professor of Astronomy at Oxford, was also troubled by Baily's disclosures. Richard Yeo writes: "There is evidence from the debates of the 1830s that this was not merely a secondary

issue but one which contained serious implications for assumptions about science.... Pleading with Whewell to enter the debate, Rigaud said that ‘if Newton’s character is lowered, the character of England is lowered, and the cause of Religion is injured’.”⁵⁶

Whewell’s three-volume *History of the inductive sciences* appeared in 1837. In this work, Whewell endeavoured to show that great scientists and philosophers are both intellectually and morally exemplary. “Thus,” as Geoffrey Cantor put it, “not only was Newton amply endowed with the apposite intellectual qualities, but he was also, in Whewell’s opinion, morally virtuous — ‘candid and humble, mild and good’”.⁵⁷ Not surprisingly, Whewell’s position on the Newton/Flamsteed matter tended to favour the former, since Flamsteed, “though a good observer, was no philosopher ... and was incapable of comprehending the object of Newton’s theory”.⁵⁸ Rigaud also contributed new information to the discussion, publishing two works containing valuable, and relevant, documents. The first, a short *Historical essay on the first publication of Sir Isaac Newton’s Principia* (Oxford, 1838), revealed previously unknown facts about Halley, as well as some of his correspondence with Newton, while the second, the more substantial *Correspondence of scientific men of the seventeenth century* (Oxford, 1841), comprised letters dating from 1606 to 1742 and included Newton, Flamsteed, Halley, Cotes, Barrow, Collins, Wallis, Huyghens and Hooke among the correspondents. De Morgan provided a thorough contents list and index in 1862.

De Morgan appeared on the scene in the late 1830s with articles on various related matters for the *Penny cyclopaedia*. However, his first major contribution to Newton scholarship was a forty-page biography for the *Cabinet portrait gallery of British worthies* in 1846. This, according to Sophia De Morgan, “was, after Baily’s *Life of Flamsteed*, the first English work in which the weak side of Newton’s character was made known”.⁵⁹ Indeed, a substantial portion is taken up with a discussion of Newton’s flaws. “The great fault, or rather misfortune, of Newton’s character was one of temperament”,⁶⁰ he wrote. “This ... showed itself in fear of opposition: when he became king of the world of science it made him desire to be an absolute monarch; and never did monarch find more obsequious subjects. His treatment of Leibnitz, of Flamsteed, and (*we believe*) of Whiston⁶¹ is, in each case, a stain upon his memory.”⁶²

De Morgan’s revisionism, coupled with a strong desire to do justice to the memory of Leibniz, resulted in a series of articles relating to the calculus controversy and, in particular, to the *Commercium epistolicum*.⁶³ His first paper on the subject actually cleared up a point in favour of Newton. As far as published sources were concerned, the committee appointed to produce the *Commercium epistolicum* consisted of six men, all British. However, in a letter published in Raphson’s *History of fluxions* (London, 1715), Newton asserts that evidence was “collected and published by a *numerous* Committee of gentlemen of *different nations*”.⁶⁴ He thus seems to be misleading his correspondent into the false

belief that the Committee was an impartial body.

However, upon examining the Royal Society's own minutes, De Morgan discovered that at later dates, four extra people, including two non-Britons, were added to the Committee, one of whom was Abraham De Moivre (1667–1754). These additions went unrecorded in print, except in an obscure French eighteenth-century biography of De Moivre in De Morgan's possession. This book also stated that his appointment "drew De Moivre out of the neutrality which till then he had observed",⁶⁵ a passage which intrigued De Morgan, since the author clearly implied "that the mere fact of joining the Committee was destruction to the character of a neutral".⁶⁶ His conclusion could only be "that the Committee in question was thought at the time not to be a judicial body, but one of avowed partizans".⁶⁷

Believing the matter to be of some importance, De Morgan "drew up a few words on this discovery, and sent them to the Royal Society. I thought they would be a *charta volans* for the *Proceedings*, etc. To my very great surprise, they were printed in all the dignity of the *Philosophical Transactions*, in which no historical paper has ever appeared, that I know of — certainly none within the century".⁶⁸ Inspired by this apparent interest in his research, he wrote a second paper, this time favouring Leibniz, which he again submitted to the Royal Society, entitled "A comparison of the first and second editions of the *Commercium Epistolicum*". His principal reason for sending it there was "that the memory of Leibnitz has a peculiar claim upon that body for reparation of many wrongs"⁶⁹ since "the Royal Society was made the instrument by which a signal injustice was perpetrated".⁷⁰

The Royal Society, it appears, did not entirely agree, and De Morgan was informed that "the Council of the Royal Society have not considered your communication ... adapted for publication in the *Philosophical Transactions*".⁷¹ The official view was that "if the question of repairing a wrong done 140 years ago be entertained, it must be entertained in a much more formal & solemn manner"⁷² than by the publication of a single paper. If reparation was to be made, "it should be done by a committee appointed for that purpose."⁷³ Paradoxically however, the Society was also of the opinion that "it is no peculiar duty of the Council of today to vindicate or to blame the proceedings of their predecessors".⁷⁴ So there the matter rested. The paper was never published, but was interred in the Royal Society archives, where it remains to this day..⁷⁵

The Society's decision irritated De Morgan intensely and in more than one of his later works he referred to it with annoyance. "I freely and unreservedly blame the Council of the Royal Society ... for not printing the account of the variations mentioned above", he wrote, adding, "they missed a golden opportunity".⁷⁶ But he retained his sense of humour, opining that

the excuse that this act of justice would require a Committee is laughable, unless the logic is as follows

According to our forms, justice can be done to Leibnitz only by a Committee.

But a Committee of our Society never does justice.
Therefore the thing proposed is impracticable.⁷⁷

De Morgan's findings did eventually see the light of day. In 1848, he re-wrote his paper and published it, with a slightly different title, in the *Philosophical magazine*. In it he pointed out no fewer than twenty-one undeclared additions and alterations to the second edition of the *Commercium epistolicum* (published in 1725) which hardened the language of the report against Leibniz, making it appear to accuse him of plagiarism. Although not all the changes were significant, De Morgan observed that "the general tendency of the additions to bring out the unfairness of the original, and to convert hints into assertions, is curiously exemplified".⁷⁸ This amounted to "the falsification of a record in a matter affecting his [Leibniz's] character, done under the name of the [Royal] Society"⁷⁹ and, being "unfortunate enough to differ from the general opinion in England as to the manner in which Leibnitz was treated",⁸⁰ it fell to De Morgan to set the record straight.

However, the matter was far from closed. In De Morgan's experience, he had yet to "come fresh to this controversy of Newton and Leibnitz without finding new evidence of the atrocious unfairness of the contemporary partisans of Newton".⁸¹ Sure enough, further testimony came to light with the publication of Leibniz's manuscripts in the Royal Library of Hanover by C. I. Gerhardt,⁸² and of Joseph Edleston's *Correspondence of Sir Isaac Newton and Professor Cotes* in 1850, and De Morgan returned to the subject. His article for the *Companion to the almanac* of 1852 was the first English consideration of the priority controversy since the discovery of "the independent proofs of the separate invention of Leibnitz"⁸³ found among his papers, which included "various original drafts, containing problems in which both the differential and integral calculus are employed".⁸⁴

Here at last was definite evidence fully to vindicate Leibniz from the charge of plagiarism, a charge which, it was always maintained, had been levelled by Newton's supporters — their leader not lowering himself by direct involvement. However, in another paper of 1852, De Morgan questioned even this, casting yet more doubt on the honourable role of Newton in the dispute. He claimed that the anonymous author of the preface to the second edition of the *Commercium epistolicum* and an account of it in the *Philosophical transactions* of 1714–15 was none other than Newton himself. This hypothesis remained unproved until 1855, when Sir David Brewster published his elaborate new biography of Newton, containing a substantial body of new material derived from unpublished documents. "Professor De Morgan", he stated, "had made it highly probable that both the review and the preface were written by Newton. Of the correctness of this opinion I have found ample evidence in the manuscripts."⁸⁵

Brewster's *Memoirs of the life, writings, and discoveries of Sir Isaac Newton* (Edinburgh, 1855) was nearly two decades in the making. Conceived as a necessary reply to Bailly's *Life of Flamsteed*, its length was increased, firstly by its

use of fresh documentary evidence, and secondly by the growing need to defend Newton from the charges accruing against him. De Morgan welcomed Brewster's endeavour and provided him with information on various points even though, as Brewster was the first to admit, "on a few questions in the life of Newton, and the history of his discoveries, my opinion differs somewhat from his".⁸⁶ Nevertheless, Brewster was able to confirm "from the documents in my possession, many of his views on important points which he was the first to investigate and to publish".⁸⁷

However, despite the mass of new evidence and the revelations of Baily and De Morgan, Brewster's *Memoir*, like his previous chronicle, stops little short of idolatry. Though undoubtedly the most detailed and exhaustive biography of Newton up to that time, it was still a thoroughly partial account, and nowhere is this bias more blatant than in his discussion of the priority dispute. Although some of De Morgan's findings are accepted, others, notably those favourable to Leibniz, are completely ignored. Indeed, one would scarcely believe that Brewster had read the works of De Morgan which he cites: his conclusion on Leibniz reads, word for word, identically to his judgement of 1831.⁸⁸

It was not only in their opinions that Brewster and De Morgan differed. In their attempts to redress the historical balance, they emphasized two very different aspects of Newton's character. Indeed, as Paul Theerman persuasively argues, perusal of the two men's biographies tells us as much about the authors' personalities as that of their mutual subject: "Brewster was characteristically concerned with public propriety and position, De Morgan with private morals.... Brewster, a more public man concerned with promoting a more prominent status for the scientist, meshed his interpretation with the prevailing political ideas of the 'man of capacity'. De Morgan evoked instead an image of the solitary and perhaps eccentric scholar."⁸⁹

Immediately prior to publication, De Morgan had been commissioned to write a review for the Edinburgh-based *North British review*. He had already stated his view, in a letter to Lord Brougham, that Brewster "has done very good service, though he is a partisan".⁹⁰ His critique was a thirty-page extension of that opinion. He stopped short of echoing Whewell's belief that such a monumental biography would be better undertaken by "some person not so onesided and rhetorical as Sir David",⁹¹ but agreed that Brewster was "still too much of a biographer, and too little of an historian"⁹² for such a project. He argued: "Newton always right, and all who say otherwise excathedrally reprov'd is a case for ostracism.... But Newton of whom wrong may be admitted, Newton who must be defended like other men, and who cannot always be defended, is a man in whom to feel interest even when we are obliged to dissent from his eulogist."⁹³

De Morgan's final opinions on the Leibniz affair are direct and unequivocal. "I have no doubt", he wrote in a letter to Brewster, "that Leibnitz was used by the English with every sort of unfairness, and that Newton was a party to the ill usage.... I think that the attempt to show that it was *possible* that Leibnitz could

have got any hint from what he saw of Newton's was a piece of effrontery. I think that Newton himself acted in a manner not becoming a gentleman in several particulars."⁹⁴ In his review, he continued: "We shall not stop to investigate the various new forms in which Sir D. Brewster tries to make him [Leibniz] out-tricking and paltry. We have gone through all the stages which a reader of English works can go through. We were taught, even in boyhood, that the Royal Society had made it clear that Leibnitz stole his method from Newton. By our own unassisted research into original documents we have arrived at the conclusion that he was honest, candid, unsuspecting, and benevolent."⁹⁵

According to De Morgan's wife, "Biot, who had been a worshipper of Newton early in the century, wrote to Mr. De Morgan at the time, expressing his satisfaction and concurrence in the statements of the *North British Review*. He received from my husband a copy of the memoir, with which he was greatly pleased."⁹⁶ Brewster, however, was less satisfied with De Morgan's criticism of his historical analysis⁹⁷ and, it appears, never contacted him again. Yet De Morgan was even more plainspoken in private than on the printed page, as witness a letter from him to John Herschel in 1867. In it, he calls Brewster "the king of slapdashery", continuing: "He is now very old, and writes without any thinking: he never wrote with much...."⁹⁸

6. NEWTON AND HIS NIECE

In the course of many years research on the life of Newton, a query had arisen, which today would be considered so minor as to render it almost irrelevant, but which to De Morgan and many of his contemporaries was every bit as vital as the question of the calculus controversy. This was the issue of the marital status of Newton's niece, Catherine Barton (1680–1739). She was known to have lived in the house of Newton's friend and patron Charles Montague (1661–1715), later the Earl of Halifax, but the relationship between the pair was never publicly well-defined. Consequently, writers from Voltaire onwards had been hinting (without proof or contradiction) that Newton's appointment to lucrative posts at the Mint had more to do with "a pretty niece ... than the theory of gravitation".⁹⁹

Needless to say, De Morgan with his instinctive sense of propriety, not to mention his insatiable appetite for anything Newtonian, was intrigued by this question. From what evidence he could glean, he came to believe that Catherine Barton "was *privately married* to Lord Halifax, probably before his elevation to the peerage, and that the marriage was no very great secret among their friends".¹⁰⁰ Given that a marriage had occurred, he believed "the most probable reason for the concealment was, that it was contracted at a time when the birth and station of Mrs. Barton would have rendered her production at court as the wife of Montague an impediment to his career".¹⁰¹ In any case, De Morgan rejected the charges that Newton owed his job at the Mint to his niece, maintaining that "scientific assistance was then so sorely needed, that no hypothesis relative to

any niece would be necessary to explain the phenomenon of Newton's appointment".¹⁰²

Confirmation of his theory, as he saw it, came in 1856, with the purchase of a letter by Guglielmo Libri (1803–69), an Italian antiquarian and historian of mathematics. Written by Newton in 1715, it tells of "the concern I am in for the loss of my Lord Halifax, and the *circumstances in which I stand related to his family*"¹⁰³ — the italics are De Morgan's. This reinforced his belief that "if Newton's niece lived with Lord Halifax, it was as his wife".¹⁰⁴ He assembled his thesis into an article for the 1858 edition of the *Companion to the almanac*, but it was rejected by the editor "on the ground of its not dealing with a subject of general interest. It was suggested to Mr. De Morgan to alter or curtail his writing, or to furnish another article, and he refused to do either. This was the cause of his discontinuing his contributions to the *Companion to the Almanac*".¹⁰⁵

De Morgan's interest in the subject did not abate, however. His account was revised and added to between 1864 and 1866, and in his last years, enlarged again. After his death, his wife and his ex-pupil Arthur Cowper Ranyard (1845–94) published the essay as the short book (158 pages) *Newton: his friend: and his niece* (London, 1885). Perhaps predictably, the response to this much-delayed work was largely one of neglect and, according to Frank Manuel's *Portrait of Isaac Newton* of 1968, "disconcerting revelations about Newton's personality by ... Augustus De Morgan were, after an initial shudder, forgotten".¹⁰⁶

The limitless fascination for the "psychological question of ... the moral character of Newton",¹⁰⁷ shown especially by De Morgan, Brewster and Whewell, has itself to be understood in its historical context. As we have seen, Whewell in particular drew strong links between moral character and high intellect, a belief also firmly held by Brewster. However, as Richard Yeo has demonstrated, "by the middle of the nineteenth century, Newton was a far more complex figure than the celestial or divine genius lauded by his contemporaries. While still exalted as the apex of scientific achievement, his genius was seen as more human in kind, and could not be dissociated from the evidence of passions, lapses, and delusions which cast severe doubts on the previous convictions about the affinity of intellectual and moral virtue."¹⁰⁸

Thus Yeo says that "neither Whewell, Brewster, nor De Morgan was able to reinstate unequivocally the alliance between intellectual and moral virtue".¹⁰⁹ However, whereas this programme was essential to Established Church members such as Brewster and Whewell, De Morgan's nonconformity removed this objective from his agenda, leaving him considerably more room for manoeuvre. He wrote: "The scientific fame of Newton ... gave birth to the desirable myth that his goodness was paralleled only by his intellect. That unvarying dignity of mind is the necessary concomitant of great power of thought, is a pleasant creed, but hardly attainable.... [W]e live in discriminating days, which insist on the distinction between intellect and morals."¹¹⁰ De Morgan's secularity thus enabled

him to pursue the question of Newton's private morals for their own sake, without reference to scientific greatness or religious affiliation, which was, to him, irrelevant. He therefore distinguished himself from his peers by attempting, in the words of Joan Richards, "to understand his mathematical predecessors not merely as intellectual forefathers but as human beings".¹¹¹

7. ARITHMETIC

We now come to an area in which publications by De Morgan are fewer in number but no less interesting. Indeed, the very fact that he was writing on the subject at all was important. "The history of Arithmetic," he said, "as the simple art of computation, has found little notice from the historians of mathematics in general. They shew themselves deficient in the knowledge of its progress, and of the connexion of that progress with the rest of their subject."¹¹² Although it had been partially considered by Wallis, Dechales, Heilbronner, Kaestner, Leslie, Delambre and Libri in their respective histories or bibliographies, the history of arithmetic, according to De Morgan, was never treated as a subject in its own right. Peacock's article for the *Encyclopaedia metropolitana* was the singular exception and thus, in De Morgan's opinion at least, "the only work which can be called a history of arithmetic".¹¹³

Yet De Morgan did not attempt to remedy the dearth of thoroughgoing arithmetical histories. In common with all other areas of his historical work, he never wrote a definitive study, although the introduction to his *Arithmetical books* (London, 1847) — of which more presently — contains a good outline of the subject's progress from the Middle Ages. Instead, he preferred to comment on particular aspects of the subject, such as the introduction of the symbols for addition and subtraction. Libri, in his *Histoire des sciences mathématiques en Italie* (Paris, 1838),¹¹⁴ had attributed their invention to Leonardo da Vinci upon examination of one of his manuscripts in Paris. However, in a brief but intriguing paper of 1842, De Morgan cast some doubt on this hypothesis, commenting on the use of the symbols in da Vinci papers which he had inspected at the British Museum. He found that in the London manuscripts, + was used, not to signify addition, but to represent the number 4. He concluded that "it would be a strange thing if Da Vinci, having got into the habit of using + for 4, should afterwards fix upon this very + as the sign of addition".¹¹⁵

However, De Morgan's main contribution to the + and – question came over twenty years later when a friend of his, John Bellingham Inglis, "whose collection of old books swarms with rarities", gave him a work on arithmetic printed in 1489, with the remark that "books which he could not use himself he liked to put into the hands of those who could use them".¹¹⁶ The book, entitled *Behede und hubsche rechenung auff allen kauffmanschaft* [sic], was written by one John Widman of Eger, who was mainly known as a medical author. On close examination, De Morgan noticed frequent use of the + and – signs in various places.

Being well aware that “the latest historical writers give the invention of + and – to Christopher Rudolf, whose first edition is of 1522 or 1524”,¹¹⁷ De Morgan realized that “by this application of a principle not universal among book-collectors, [Inglis] has added forty years to the known age of the signs + and –”.¹¹⁸

However, he soon recognized that the symbols as used by Widman did not have entirely the same function as they did in contemporary arithmetic. As he explained to John Herschel, “they did not mean *add*ⁿ & *subt*ⁿ but, as their names impart, *more* and *less* (i.e. than were wanted). The original meaning of $7 + 3$ is ‘choose 3 for your answer and you get 7 more than you want.’”¹¹⁹ Rudolf’s *Die Coss* of 1524 was apparently the first work to feature the modern usage of the symbols, but no copies were known to exist by the nineteenth century. The situation was complicated further by Michael Stifelius who published a second edition of Rudolf in 1571. “This same Stifelius”, De Morgan tells us, “had published his own work on algebra in 1544, in which he makes a large use of + and –. Did he adopt the signs for himself, and then introduce them into his edition of Rudolf? Or did he take them into his own work from the first edition of Rudolph? Probably the second; but not certainly.”¹²⁰

Correspondence on this issue resulted in the same conclusion. His friend, and fellow bibliophile, John Thomas Graves (1806–70)¹²¹ wrote to him in September 1864, “I have no doubt that Stifel takes his rules of + and – as well as the signs themselves from Rudolff. In fact he says so, both in his *Arithmetica Integra* and in his edition of Rudolff.”¹²² Yet, although “either Rudolph or Stifelius is, so far as known, the real introducer of these signs, as at present used”,¹²³ thanks to De Morgan’s keen eye, it was shown that, since their first (recorded) appearance was in Widman’s book on commercial arithmetic of 1489, they did not actually invent them. Nevertheless, it was they “who first saw the place which the abbreviations were to occupy, and gave them that place, so as to bring out their force and effect”.¹²⁴ Despite this very significant discovery, however, De Morgan still thought it “quite possible that + and –, as *more* and *less*, may be fished out of a manuscript of the twelfth or thirteenth century”.¹²⁵

The original meaning of + and – also influenced De Morgan’s opinion as to the origin of the symbols themselves. Initially, he believed them to have been, like our number system, of Hindu origin. Since Indian mathematicians used a dot for subtraction, De Morgan thought it likely “that in the first instance the Hindoo dot was elongated into a bar, to signify subtraction, addition having no sign: and that the first who found it convenient to introduce a sign for addition, merely adopted the sign for subtraction with a difference”.¹²⁶ However, on examination of Widman, he observed that the “presentation of data is not the doing of the arithmetician, as such: it seems to be served up direct from the warehouse.... It may be suspected that + and – were warehouse marks ... perhaps painted or chalked on the chests”.¹²⁷ Whatever the true interpretation was, he wisely remarked: “We know that the inventors of our symbols attached very little importance to them: and would have stared in wonder if they had been told

that these trumpery tricks of abbreviation would one day have a philosophy of their own, and would make inquirers curious about their origin."¹²⁸

Other arithmetical topics that De Morgan considered included the respective histories of decimal fractions and of interest.¹²⁹ These are interesting to read but are among the more minor of his historical works, complementing rather than obsolescing their treatment in Peacock's treatise. Similarly, his discussion of Hindu arithmetic¹³⁰ added little to what had already been revealed by Colebrooke. Nevertheless, both considerations provide strong evidence that, even when De Morgan was not contributing anything new to the subject, he was keen to promote and examine the historical work of others. In sharp contrast, his discussions of applied arithmetic and, in particular, its relation to the calendar, are very original contributions, since these areas were almost totally disregarded by other scholars.

An example is his paper "On ancient and modern usage in reckoning", which highlighted unrecognized distinctions between old-fashioned and contemporaneous methods of performing everyday calculations and the confusion thus caused. He tells us, "European counting, antecedent to the introduction of the Indian numerals, was entirely fashioned upon the Roman system, in which no symbol for *nothing* exists. The Indian zero, or cipher, in the first instance, was not an express symbol for *nothing*.... The notion of *absence of value*, or *value not yet attained*, ... was an idea of very small growth, ... but not a part of its first intention."¹³¹ Consequently, the introduction of the Indian system of numeration divided those who counted from 0 and those who started at 1. This resulted in much confusion when specifying, for example, how many days Friday was from Wednesday: "The necessity of taking in the terminus of reckoning on each side, follows immediately from *one* being the commencement of all counting; those who begin from *nought*, make 0 to represent the initial term, *from* which they reckon. The former reckon *three* from Wednesday to Friday; the latter *two*."¹³²

By a careful examination of medieval acts of parliament, he found that the Roman system of counting was, for some considerable time, sustained by English law: "The old statutes fully satisfy us that, in the middle ages, the time *from* a day and the time *after* a day included that day."¹³³ Further scrutiny revealed that this continued to be the case throughout the Tudor and Stuart periods until the time of William III when the modern system of reckoning came into favour. De Morgan also undertook an analysis of the work of the sixth-century founder of the Christian Era, Dionysius, in an attempt to determine whether the nineteenth century should be reckoned as beginning in 1800 or 1801. However, since the concept of grouping years into centuries is comparatively recent, he concluded that the attempt to determine when earlier centuries began is largely irrelevant, since "we hold it clear that no usage can exist, except one of very modern times".¹³⁴

Despite this, he makes his own opinion on the matter very clear. During the course of his investigation, he had found "little or no allusion to how people *did*

count; the matter was assumed to demand settlement by the way in which people *ought* to count. Great pains were taken to prove that there must have been a year 0 after the Christian era; and those who would attribute the habits of a modern mathematician to the old computers — who reckoned I, II, III, IV, &c, and had never dreamed of a zero symbol — made a very plausible figure with those who could not correct them.”¹³⁵ Therefore, he says, since there was no such tradition in Antiquity, to correctly determine the position of the nineteenth century, we must follow the present practice and regard the first year as being 1801 and the last as 1900.

The juxtaposition of the evolution of arithmetical symbols and calendar reckoning, as well as issues of use and understanding, clearly illustrates the vast range of De Morgan’s interests in just one particular field. Moreover, the great contrast between these obscure areas of the history of arithmetic and the study of Isaac Newton further exemplifies how his curiosity could alternate between subjects of widespread attraction and those that went largely ignored. His interest in these neglected areas, of which arithmetic was just one example, was to him absolutely vital for a complete understanding of the history of science. In much of his historical work, he strove to justify this belief, writing: “It is ... essential to true history, that the minor and secondary phenomena of the progress of mind should be more carefully examined than they have been ... so that he [the historian] may write upon effects as well as causes.”¹³⁶

8. BIBLIOGRAPHY

When reading De Morgan’s historical work, one is struck by how many of his papers were inspired by the casual perusal of a particular book. This is remarkable, but not surprising; he was one of the nineteenth century’s most notable bibliophiles and made no secret of the fact that his favourite place of retreat was either a library or a second-hand bookshop. His own library was one of the finest accumulations of books on the history of mathematics in the country, growing so large that he was forced to move house to accommodate the sheer number of volumes. At his death, the collection stood at an estimated three thousand items, many of which were exceedingly rare. Not surprisingly, it was soon keenly sought after for purchase — initially, and unsuccessfully, by the infant London Mathematical Society — being finally bought by Lord Overstone (1796–1883) who donated it in its entirety to the University of London Library, where it served as the founding collection.

One is not astonished to find, therefore, that much of De Morgan’s work on history is devoted to mathematical bibliography, since, as he said himself, “the history of science is almost entirely the history of books and manuscripts”.¹³⁷ One book that particularly fascinated him was the *Arithmetic* of Edward Cocker, on whom he wrote an entry in the *Penny cyclopaedia*. *Cocker’s Arithmetick* (London, 1677) was the first book on the subject to confine itself purely to

commercial calculations, as opposed to using proofs and reasoning. What especially intrigued De Morgan was that, despite the book's thirty-seven editions and wide renown via subsequent school treatises, "there is no copy of any edition either in the British Museum, the libraries of the Royal Society or London Institution, or (so far as the old catalogues go) in that of Sion College, or of the Faculty of Advocates at Edinburgh. We have opened the title-page from a mutilated copy of the 37th edition, being the only one we ever saw exposed for sale in London."¹³⁸

This statement prompted the following letter, which was sent to De Morgan (probably in 1837 or 1838), enclosing a copy of the twentieth edition of Cocker dating from 1700:

Sir

Although I cannot claim the honor of a personal acquaintance with you yet I trust that I have not taken too great a liberty in sending you the little volume enclosed with this.

Hearing accidentally that you were the author of the mathematical articles in the Penny Cyclop. was the reason of my forwarding it to you, having recently read the biography of Cocker pub^d in it. It is not a very clean exemplar, yet the best I have ever seen and I can only say that it is through no fault of mine that I give you not a better one. I beg you will do me the honor to accept of it as a slight testimonial of the gratitude I feel for the delight I have experienced in perusing your commentary on the fifth book of Euclid's Elements and others of your published treatises.

Believe me, to remain,

Sir

Your obedient Servt.

J. O. Halliwell.

35 Alfred Place.¹³⁹

James Orchard Halliwell (1820–89) is best remembered, if at all, for his Shakespearean studies and the publication of old English nursery rhymes. However, at the time of writing to De Morgan, he was actively involved with the history of science. An enthusiastic antiquarian and collector of manuscripts, he was elected a Fellow of both the Royal Society and the Society of Antiquaries at the age of just nineteen. From his manuscript collection, he published a book, *Rara mathematica, or a collection of treatises on mathematics*, in 1839 which included a rare treatise by Sacrobosco on numeration. As a result of similar interests, not to mention the above letter, Halliwell quickly became friendly with De Morgan and the following year invited him to join a new society which he was in the process of forming.

Called the Historical Society of Science, its sole aim was "to render materials for the history of the Sciences accessible to the general reader, by the publication of manuscripts, or the reprinting of very rare works connected with their

origin and progress in this country and abroad".¹⁴⁰ It speedily recruited nearly two hundred members including Francis Baily, Libri, Peacock, the French geometer and historian Michel Chasles (1793–1880), British scientist Michael Faraday (1791–1867), the mathematician James Joseph Sylvester (1814–97) and the Savilian Professor of Geometry at Oxford, Baden Powell (1796–1860).¹⁴¹ Suggested titles for publication abounded, including "Treatises on Geometry written in England during the 13th and 14th centuries; including an hitherto inedited treatise on that subject, by Roger Bacon" and "A catalogue of the scientific manuscripts formerly in the library of Dr. John Dee of Mortlake".

De Morgan took an active role from the beginning, being a member of the Society's council and, as is evidenced from his correspondence, endeavouring to solicit new members. For example, Ada Lovelace (1815–52), scientific enthusiast and daughter of Lord Byron, was his friend and private pupil. He recruited her for membership of the new society although, due to the chauvinistic attitudes of the time, her name could not be included on the list of subscribers. He wrote to her in the summer of 1840: "I forwarded to Lord Lovelace the other day a prospectus of a Society now in process of formation for printing scientific manuscripts which have not been hitherto printed.... As you will certainly take an interest in the results of its labors, if you continue your studies, I should recommend *your* being a member, with Lord Lovelace as your proxy."¹⁴² Lord Lovelace's name was duly inserted in the list. De Morgan can here be seen vigorously attempting to build up an active group of people also interested in the history of science.¹⁴³

In spite of this initial surge of enthusiasm, however, the Society published only two books, both in 1841, and was dissolved four years later.¹⁴⁴ Reasons for its failure are difficult to ascertain, but were probably financial, due to lack of subscriptions, since Halliwell's management had certainly come under some criticism. The Society had also received considerable unwanted attention due to the accusation by Trinity College Cambridge that Halliwell had stolen many of his manuscripts from their collection. Although the case was never proved, the defendant's story remained dubious, to say the least.¹⁴⁵ Halliwell offered a slightly different account of the Society's failure when he mourned the chronic indifference of the majority of the scientific community to their own history: "these discoveries seem to have attracted little attention from scientific men ... on account of that lamentable apathy towards matters of history which is too frequently characteristic of the lover of demonstration."¹⁴⁶ *Plus ça change...!*

The extent of De Morgan's bibliographical knowledge was first revealed in an article for the *Companion to the almanac* in 1843 in the form of a catalogue of every single published work with relevance to the history of science of which he was aware. He explained:

In most bibliographical lists many works are contained which the maker of the catalogue has never seen, having copied the titles and dates from some predecessor. The confusion which this has introduced into the subject of

mathematical history is well known to all who have attempted to reconcile descriptions of books with each other or with the books themselves.... To secure ourselves from mistakes of this sort, *we give in the present article no account of any book, tract, pamphlet, or other printed document whatsoever, unless such book, &c. be before us at the moment of writing down its date, place, and title.*¹⁴⁷

Even with this restriction, De Morgan was able to produce a detailed register of over 250 items in categories including pure and mixed mathematics, physics, astronomy, philosophy, dictionaries, biography, epistolary correspondence, chronology and bibliography itself. Works by Heilbronner, Hutton, Biot, Delambre, Woodhouse, Peacock, Whewell and Libri previously alluded to in this paper are all included, as well as some of their other publications. The myriad titles that De Morgan had managed to assemble covered over three hundred years, from the *Vita omnium philosophorum* (Paris, 1530) to D-F-J. Arago's *Analyse historique et critique de la vie et des travaux de Sir William Herschel* of 1842. Amongst the multitude of other publications were John Ward's *Lives of the Professors of Gresham College* (London, 1740), Pierre Gassendi's *Vita Tychonis Brahei* (The Hague, 1655) and Charles Babbage's *On the decline of science in England* (London, 1830).

His next major bibliographical undertaking was still more ambitious. In January 1847, he wrote to John Herschel about the ensuing project: "My next job is a list of writings in Arithmetic of which I shall catalogue about 300 — with a list of 1250 *names* only — from Euclid down to such fry as myself — through all ages."¹⁴⁸ The result was a 124-page catalogue of *Arithmetical books from the invention of printing to the present time* (London, 1847). Probably the most famous, and certainly the best, of his works on mathematical bibliography, it was inspired by, and dedicated to George Peacock, "the only Englishman now living who is known, by the proof of publication, to have investigated both the scientific and bibliographical history of Arithmetic".¹⁴⁹

Peacock himself was an ardent supporter of the enterprise. "Your list", he told De Morgan, "will be very interesting: still more so if the works could be collected, so as to furnish the means of tracing the progress of methods & processes".¹⁵⁰ As with his previous catalogue, *Arithmetical books* contained no book which De Morgan had not actually seen, its subtitle being *Brief notices of a large number of works drawn up from actual inspection*. With regard to the works themselves, De Morgan made no selection for inclusion whatsoever. "No book that I *have* seen during the compilation has been held too bad to appear; no book that I *have not* seen too good to be left out."¹⁵¹ His rationale was that "the most worthless book of a bygone day is a record worthy of preservation. Like a telescopic star, its obscurity may render it unavailable for most purposes; but it serves, in the hands which know how to use it, to determine the places of more important bodies."¹⁵²

Here again is demonstrated De Morgan's belief in the importance of reporting

previously unknown fragments of scientific history from the conviction that everything has some value, no matter how small. It should not be assumed, he argued, "that because a book is wholly unknown, it proves nothing in the history of science. A book so thoroughly lost as that of Witt,¹⁵³ contains a nearer approach to the decimal point than was made by Napier."¹⁵⁴ However, since such minor works would always turn up from time to time, he acknowledged that any catalogue such as his own would never be entirely complete. Undaunted, he continued to extend his list long after its publication, requesting his readers to "furnish me with information on works which I have not seen [since] I think it probable that any one who has had the curiosity to rescue three books of arithmetic from a stall, will find that one of them is not in this list".¹⁵⁵ His manuscript additions can be seen in the University of London Library (Catalogue no. MS 239).

The chronological catalogue contained in *Arithmetical books* itself was the most comprehensive work of its kind undertaken up to that time. Nearly four hundred items are listed, the earliest being a Venetian work of 1488, the most recent, the fifth edition of De Morgan's own *Elements of arithmetic* (London, 1846). He justified its inclusion in the following characteristic way: "Books of bibliography last longer than elementary works; so that I have a chance of standing in a list to be made two centuries hence, which the book itself would certainly not procure me."¹⁵⁶ He also provided, at the end of the work, an index of a staggering 1,580 reported authors of arithmetical works, nearly a third of whom had been mentioned in the main text. The book is also valuable for its learned digressions on various points in arithmetical history, such as the invention of the decimal separator, the imperial measure of a foot, and, of course, *Cocker's Arithmetick*.

A consistent feature of all of De Morgan's bibliographical work is its accuracy; he frequently complained about the lack of similar characteristics in existing catalogues of scientific works. "We have never examined a point of mathematical history", he wrote, "without finding either error or difficulty arising from bad bibliography".¹⁵⁷ The reason, according to De Morgan, was that "the study of *bibliography*, that is, of books as books, in all matters which are requisite to avoid errors and difficulties just alluded to, has been left to librarians and to bibliomaniacs, as they have been called".¹⁵⁸ The consequence was that "for a long time it was not thought necessary to describe the titles of books with accuracy, and even the lists of professed bibliographers were drawn up with mere paraphrases of titles".¹⁵⁹

The situation was not helped by the very real difficulties of correctly and adequately describing old books. De Morgan highlighted the four main problems. Firstly, the inadequacy of many old catalogues, upon which many scientific historians were forced to rely owing to the scarcity of the original works themselves. Due to insufficient examination by these previous bibliographers, misrepresentation of book's contents was very frequent. One of the most common

mistakes that De Morgan pointed out was with regard to authorship. "There is a loose system of description," he said, "under which any prominent proper name is taken for that of the author.... If a friend or patron should contribute a preface, he will perhaps get credit for the whole; thus Billingsley's English Euclid has been entered under the works of John Dee, who wrote the introduction."¹⁶⁰

Secondly, the dates of some works were hard to ascertain due to inconsistencies such as multiple title pages, different preface dates, or no date given at all. The third problem was illustrated by De Morgan using a copy of Francis Schooten's Latin translation of Descartes's *Geometry* (Leyden, 1649). This is certainly the second edition of Descartes, but not of Schooten. Consequently, confusion had arisen over what should be called the second edition. This misapprehension was compounded by the second of Schooten's editions of Descartes from 1659, which, according to De Morgan, "has on the fly-title, 'Renati Descartes Geometria, Editio Secunda' — a wrong description. Thus it appears that the titles of the books themselves may contain the very errors which it is the tendency of bad catalogues to create."¹⁶¹

Finally, due to some publishers' practice of binding more than one work in a single volume without advertising the fact, a book may contain more than appears from a cursory glance at its title page. De Morgan informs us that two things were very common in the sixteenth century, namely, "the binding up of different publications in one, and the distribution of one publication under different title-pages, often without any mark by which to know that all the titles belong to one work. Hence catalogues sometimes represent different publications as one, and sometimes represent one publication under several heads."¹⁶² Such problems clearly formed serious obstacles for the modern bibliographer and the only way to overcome them, De Morgan argued, would be to produce a precise and rigorous catalogue in which exact references were easily accessible.

It should be noted that, at this period, the library of the British Museum was still in its infancy and no thorough record of its contents existed. For many years, scholars such as De Morgan had been pressing for such a catalogue to be produced and, by virtue of his bibliographical expertise, and his friendship with the library's chief founder, Sir Anthony Panizzi (1797–1879), he was called to give evidence before a Royal Commission on the matter. In 1850, the Commission ruled in favour of the proposed scheme and the process of compilation began. Yet, impatient as he no doubt was to see the work completed, De Morgan urged that time be taken over its preparation so as to ensure maximum accuracy, arguing that if expediency "should succeed in hurrying the execution of this national undertaking, the result will be one more of those magazines from which non-existing books take their origin, and existing ones are consigned to oblivion by incorrect description".¹⁶³

Finally, we note *A budget of paradoxes*, probably his most widely read work. In August 1863, in a letter to Lord Brougham regarding the *Athenaeum*, he wrote, "I am on the point of giving, in that paper, a series headed 'A Budget of Paradoxes'

giving a list, with comments, of all the circle-squarers, universe-builders, &c who are in my library. I think I shall have about 200, including all the rational *paradoxers*, as I call them, who are not much known, as Gilbert, Thomas Wright, &c. They are a rare lot.”¹⁶⁴ Relying for much of its content on the author’s vast store of historical and scientific anecdotes, the Budget still deserves citation as an amusing repository for the various mathematical and scientific oddities he had accumulated over the years.

To list all the gems included would probably result in a work of considerable length in its own right, but a couple of reviews will suffice to give a flavour of its contents.

“The Decimal System as a whole. By Dover Statter. London and Liverpool, 1856, 8vo.

The proposition is to make everything decimal. The day, now 24 hours, is to be made 10 hours. The year is to have ten months, Unusber, Duoher, &c. Fortunately there are ten commandments, so there will be neither addition to, nor deduction from, the moral law. But the twelve apostles! Even rejecting Judas, there is a whole apostle of difficulty. These points the author does not touch.”¹⁶⁵

“A method to trisect a series of angles having relation to each other; also another to trisect any given angle. By James Sabben. 1848 (two quarto pages).

‘The consequence of years of intense thought’: very likely, and very sad.”¹⁶⁶

“A Budget of Paradoxes” first appeared in the *Athenaeum* on 10 October 1863 and quickly became a popular, and sometimes controversial, feature, being “in some degree a receptacle for the author’s thoughts on any literary, scientific, or social question”.¹⁶⁷ When the series ended in 1867, De Morgan was in the process of collecting materials for a second part “in which the contradictions and inconsistencies of orthodox learning would have been subjected to the same scrutiny and castigation as heterodox ignorance had already received”.¹⁶⁸ Sadly, his death in 1871 meant that this second Budget never materialized. However, a year later, his widow edited and published the articles together in one volume with a few of the author’s later additions. The book, with its witty, half-mocking style, remains a good read to this day and testimony to the fact that De Morgan’s historical knowledge was matched only by his sense of humour.

9. MOTIVATION FOR DE MORGAN’S HISTORIOGRAPHY OF ‘ACTUAL INSPECTION’

De Morgan’s historical works are characterised by two distinctive features. Firstly, a great emphasis on primary and archival sources, and secondly, a desire to construct, from the complex mass of evidence available, an accurate historical picture of events as they really occurred. One could draw the analogy of

Augustus De Morgan the mathematician doing his history in the same way as his mathematics, that is, starting from first principles (or as near as possible) and working his way to the right answer. But there is far more to it than this simplistic view. De Morgan belonged to a period intensely concerned with the faithful recovery of the past and this ambition was reflected in his historical methodology. Not only was it very similar to that of contemporaries such as Baily, Rigaud, Brewster, and Halliwell, but it typified what Richard Yeo has described as “a major development in historiography” in the first third of the nineteenth century, being distinguished by “a new critical use of sources ... [and] a greater sensitivity to the social and cultural differences between various historical periods”.¹⁶⁹

In how he *used* his history, De Morgan's aims were also somewhat similar to those of Whewell. As recent analysis has shown, by the 1830s, historians like De Morgan and Whewell were able to use the history of science extensively to support their arguments in debates about contemporary science. Joan Richards sees De Morgan's “exploration of mathematical history as part of a larger attempt to understand and explain the nature of mathematics itself...”,¹⁷⁰ a view corroborated by De Morgan himself in a speech delivered, towards the end of his career, at the inaugural meeting of the London Mathematical Society in January 1865. Here, he argued that the study of mathematical history was an absolute necessity for the furtherance of mathematical research. Only by discovering how different branches of mathematics have progressed and evolved, he argued, can the mathematical student form a correct and accurate picture of how to proceed. Furthermore, the mistakes as well as the successes of preceding generations can also be learnt from. In short, “the early study of the mind of men with regard to Mathematics leads us to point out our own errors; and in this respect it is well to pay attention to the history of Mathematics”.¹⁷¹

De Morgan's desire to discover the true facts behind the events he described, together with the realization that the past is often very partially recorded, led to a preoccupation with setting the record straight, particularly in matters concerning priority of discovery or invention. This is best evinced in his discussions of minor scientific figures such as Thomas Wright of Durham and, more notably, the Newton–Leibniz controversy. This ‘champion of the underdog’ view of history was certainly inspired, in part, by De Morgan's innate sense of gentlemanly fair play. This explains how it was perfectly consistent for him to defend Leibniz from Newtonian charges of plagiarism but also to defend Newton from accusations of immorality over his niece. For De Morgan, being pro-Leibnizian did not automatically imply anti-Newtonianism. However, this love of justice may also have arisen from the fact that he had himself been wrongly accused of plagiarism. In 1847 the Scottish logician Sir William Hamilton (1788–1856) made the charge over De Morgan's use of quantification of the predicate in his logic,¹⁷² and, whereas De Morgan had been able to prove that the charges were unfounded, the experience must have instilled a sense of solidarity with those who had been less fortunate in the past.

What especially differentiated De Morgan's history from that of his peers was his dogmatic insistence on taking nobody's word for anything he could not confirm by personal inspection. In his prefatory letter to *Arithmetical books*, he takes care to stress that the items included in his catalogue comprise "only what I have seen myself".¹⁷³ As with his anti-heroic stance, this attitude can be linked to his uncompromising nonconformist tendencies.¹⁷⁴ In common with any other study of De Morgan, the importance of his position as a "Christian unattached" cannot be overstressed in an analysis of his work in the history of science. It was one of the ruling principles of his life, resulting in his rejection of an academic career at Cambridge, his employment by the first secular College in the country, and, ironically, his eventual resignation when he believed it had abandoned its non-sectarian principles. This incessant inclination to question all authority while relentlessly adhering to firm beliefs is repeatedly demonstrated in De Morgan's histories, constituting perhaps the most powerful motivation behind his philosophy of the subject.

10. DE MORGAN'S HISTORICAL INFLUENCE

De Morgan's academic career lasted for over forty years, and his work, both as a writer and a teacher, left its mark on many who came into contact with it. Many of his pupils at University College were profoundly influenced by his wide range of interests: William Stanley Jevons (1835–82) inherited his great love of logic, Arthur Cowper Ranyard acquired a fascination for astronomy, while Edward John Routh (1831–1907), at his professor's suggestion, went to Cambridge, where he became the most successful mathematical tutor in its history. De Morgan's passion for the history of mathematics — though not his wit or literary style — was transferred to Isaac Todhunter (1820–84) who studied at University College in the 1840s before moving to Cambridge, where he became a Fellow of St John's College. While there, he acquired fame as the author of a wide variety of mathematical textbooks, many of which became standards at the time.

More importantly for our purposes, Todhunter wrote four elaborate treatises on mathematical history, with increasingly convoluted titles, starting with *A history of the progress of the calculus of variations during the nineteenth century* (Cambridge, 1861) and concluding with a posthumous *History of the theory of elasticity and of the strength of materials from Galilei to the present time* (Cambridge, 1886–93), edited by Karl Pearson. Aside from general encouragement, the only direct role that De Morgan played in Todhunter's historical work came during the research for his second volume, *A history of the mathematical theory of probability from the time of Pascal to that of Laplace* (Cambridge and London, 1865), in which the author expresses his "sincere thanks ... to Professor De Morgan ... for the kind interest which he has taken in my work, for the loan of scarce books, and for the suggestion of valuable references".¹⁷⁵

However, if one relies on the works of De Morgan which Todhunter cites for an idea of how the pupil viewed his master, it would seem that to Todhunter, De Morgan was more of a history maker than a history reporter. Of his works mentioned, almost all are mathematical, such as the *Differential and integral calculus* (London, 1842) or the *Essay on probabilities* (London, 1838), and the only vaguely historical citation is a bibliographical one.¹⁷⁶ The reason for this is very simple. De Morgan never wrote on the histories of the subjects treated by Todhunter, and any research he undertook in probability theory, for example, was purely theoretical. Hence the lack of historical references. The two historians also differed in their mode of treating their subjects. Whereas De Morgan favoured concise, easily digestible articles, Todhunter preferred lengthy tomes which, while excellently researched histories, were hardly light reading.

Perhaps the closest disciple of De Morgan's historical work was Walter William Rouse Ball (1850–1925). Another former student of University College (though he attended too late to be taught by De Morgan), Ball also emigrated to Cambridge, becoming a Fellow of De Morgan's old college, Trinity. His best-known historical works are *A short account of the history of mathematics* (London, 1888) and *A history of the study of mathematics at Cambridge* (Cambridge, 1889); both are peppered with generous selections of references to De Morgan's historical publications, the author admitting, "I have made considerable use of some of them".¹⁷⁷ Those most often quoted were *A budget of paradoxes* and *Arithmetical books*, but articles from the *Companion to the almanac* and *Penny cyclopaedia* are also cited.

When writing about De Morgan, Ball consistently exhibited a sincere and striking reverence: "the secret of [De Morgan's] undoubted power in the mathematical world ... is to be found in his historical papers and reviews, his occasional lectures on general subjects, and in the universal recognition of his desire for justice and scorn of all pretence".¹⁷⁸ He had no doubt that De Morgan's historical work would be his principal legacy, holding that "in science, ... it was mathematico-historical questions, notably the follies of circle-squarers and the Newton–Leibnitz controversy, that specially attracted his attention, and by which he will hereafter be chiefly remembered".¹⁷⁹

Yet, as has been noted, history has proved Ball wrong. For the majority of the twentieth century, De Morgan has not been remembered for his history, but for his mathematics and logic. This contrasts sharply with the situation during the fifty or so years following his death when his historical research was equally well regarded. Writing in 1908, the American historian of mathematics David Eugene Smith (1860–1944) extolled *Arithmetical books* as "still one of our best single sources, although sixty years have elapsed since it first appeared".¹⁸⁰ Smith also edited the second edition of *A budget of paradoxes* which appeared, in two volumes, in 1915.¹⁸¹ Alluding to De Morgan's Newtonian studies, Cambridge historian Philip E. B. Jourdain (1879–1919) commented: "Like everything he wrote, these essays of his are marked by scrupulous care, sanity of judgment,

and wide reading; and one hardly knows which to admire most: the breadth or the height of his mind.”¹⁸²

So why has De Morgan’s history received so little recognition in recent years? It has already been noted that De Morgan’s mode of publication differed considerably from that of Todhunter, whose histories are far more accessible today than those of his erstwhile teacher. This can be no coincidence. De Morgan was by far the more fluent writer and his historical acuity not inferior to Todhunter’s, so why is his work so neglected today? A possible explanation may be that De Morgan was not publishing the ‘right’ kind of histories: by dispersing his historical erudition through short articles in a wide variety of journals and periodicals, their combined impact was weakened. Moreover, whereas books can undergo many reprints and further editions, articles from nineteenth century journals rarely do. It is thus hardly surprising that within half a century of his death, De Morgan’s historical works were scarce and were cited with increasing irregularity by scientific historians. As early as 1889, Rouse Ball was drawing attention to the fact that the fruits of De Morgan’s historical research “are given in scattered articles that well deserve collection and republication”.¹⁸³ The situation has not changed over a century later.

De Morgan himself came close to another possible explanation in his speech to the London Mathematical Society in January 1865. In it, he complained how the history of mathematics was “unfairly neglected” by mathematicians. He went on: “It is astonishing how strangely mathematicians talk of the Mathematics, because they do not know the history of their subject.... There is in the idea of every one some particular sequence of propositions, which he has in his own mind, and he imagines that that sequence exists in history.”¹⁸⁴ The same could almost be said of historians of mathematics and the lack of knowledge *they* have of the history of their subject. Certainly every mathematical historian will know that Leibniz was an independent inventor of the calculus and was treated unfairly by Newton. But how many will know *when* and *by whom* that fact was revealed?

A reason for this may be simply that for the historian of the late twentieth century, De Morgan’s obsession with facts and bibliography may seem somewhat *passé*. This in turn could further clarify why his historical writings are currently overlooked. Whereas in the last decade, several historians have given considerable attention to mid-nineteenth century historians of science, especially Brewster and Whewell, De Morgan (with the exception of his Newtonian studies) has received comparatively little notice. Could this have something to do with his factual penchant? After all, his articles on the history of science are always far more descriptive than analytical, perhaps because he always considered himself no more than an enthusiastic amateur in the subject. This again ties in with what constitutes the ‘right’ kind of histories. In this case it would seem that De Morgan, while always prepared to offer an opinion on the subject he treated, was more concerned with providing a sound factual basis upon which others, more qualified than he, could decide.

The truth is that once a new historical fact has been uncovered, the novelty of its discovery often renders its reporter unimportant. Yet it was precisely such historical figures that De Morgan considered significant. "It would be much too strong a simile," he said, "to compare the man whose name is in the mouths of all to the engineer who lays the match to a train, and startles the world by an explosion, while no one asks who bored the rock or laid the powder",¹⁸⁵ but he insisted "that names which are now unknown to general fame are essential to a sufficient view of history".¹⁸⁶ It is therefore ironic that, as a historian at least, he should himself have become one of these lesser known personalities. But De Morgan always prided himself on being the champion of the underdog, striving to produce accurate, intelligible, but above all, fair history of mathematics. It is this, combined with the quality and originality of much of what he wrote in this area, that makes Augustus De Morgan a name historians of mathematics would be wise to remember.

ACKNOWLEDGEMENTS

I would like to thank John Fauvel, my supervisor Ivor Grattan-Guinness, and my anonymous referees for valuable suggestions made during the preparation of this paper.

REFERENCES

1. An exception is J. L. Richards, "Augustus De Morgan, the history of mathematics, and the foundations of algebra", *Isis*, lxxviii (1987), 7–30. It should also be noted that historians of *science* still make use of De Morgan's work on Newton.
2. The best bibliography of De Morgan's work is in G. C. Smith, *The Boole–De Morgan correspondence 1842–1864* (Oxford, 1982), 141–7. Additional works are cited in S. E. De Morgan, *Memoir of Augustus De Morgan* (London, 1882), 401–15.
3. Letter from G. Peacock to S. Hunter Christie, 16 Oct. 1847. Royal Society Archives: RR.1.57.
4. W. W. Rouse Ball, *A history of the study of mathematics at Cambridge* (Cambridge, 1889), 133.
5. See I. Grattan-Guinness, "Some British eccentrics: The historians of mathematics in the British Isles" (contribution to forthcoming volume on the history of historians of mathematics, in preparation under the editorship of C. J. Scriba and J. W. Dauben).
6. For a discussion of the historical work of Montucla, as well as that of other eighteenth- and nineteenth-century historians of science (including Delambre, Colebrooke and Whewell), see Rachel Laudan, "Histories of the sciences and their uses: A review to 1913", *History of science*, xxxi (1993), 1–34.
7. C. Hutton, *A mathematical and philosophical dictionary* (2 vols, London, 1795–96), i, p. vi.
8. *Ibid.*
9. For an evaluation of John Wallis the historian, see J. F. Scott, "John Wallis as a historian of mathematics", *Annals of science*, i (1936), 335–57.
10. Hutton, *op. cit.* (ref. 7), i, 95.
11. *Ibid.*, i, 248.

12. *Ibid.*, ii, 151.
13. *Ibid.*, i, 485.
14. A. De Morgan, "Delambre", in *Gallery of portraits: with memoirs*, iv (London, 1835), 165–9, p. 167.
15. P. C. Enros, "The Analytical Society (1812–1813): Precursor of the renewal of Cambridge mathematics", *Historia mathematica*, x (1983), 24–47.
16. G. Peacock, "Arithmetic", *Encyclopaedia metropolitana*, i (London, 1845), 369–523, p. 477.
17. S. E. De Morgan, *Memoir of Augustus De Morgan* (London, 1882), 393.
18. *Ibid.*, 21.
19. It is worth mentioning that De Morgan's religious scruples, strong though they undoubtedly were, did not prevent him actually taking his B.A. degree, which required acceptance of the thirty-nine Articles of Faith. It can only be assumed that he took the oath under (silent) protest.
20. A. Rice, "Inspiration or desperation? Augustus De Morgan's appointment to the chair of mathematics at London University in 1828", to appear.
21. A. De Morgan, "Polytechnic School of Paris", *Quarterly journal of education*, i (1831), 57–74, p. 73.
22. For example: (a) A. De Morgan, "On the syllogism III", *Transactions of the Cambridge Philosophical Society*, x (1858), 173–230, pp. 175 and 181, note; (b) A. De Morgan, *Syllabus of a proposed system of logic* (London, 1860), 41, note, and 44, note; (c) A. De Morgan, "On the syllogism IV", *Transactions of the Cambridge Philosophical Society*, x (1860), 331–58.
23. This is now housed in the University College archives (MS. ADD. 7). Its first page contains a charming preamble in which De Morgan says: "Such account as I can give of my family is contained in two books. The first is well known by the name of Genesis, ascribed by Jewish tradition to Moses. The second is this book itself, which my own handwriting will identify as compiled by me. Moses gave no account of his materials: I have given what I could. Moses wrote in Hebrew: I in English. Moses was a public writer, I am a private one. Many are the oppositions between me and Moses...."
24. A. De Morgan, "A budget of paradoxes", *The Athenaeum*, no. 1876 (10 Oct. 1863), 466; A. De Morgan, *A budget of paradoxes* (London, 1872), 2.
25. De Morgan, *op. cit.* (ref. 24, 1863), 467; De Morgan, *op. cit.* (ref. 24, 1872), 7.
26. A. De Morgan, "Some account of James Dodson F.R.S.", *Journal of the Institute of Actuaries and Assurance magazine*, xiv/5 (October 1868), 341–64.
27. A. De Morgan, "Old arguments against the motion of the Earth", *Companion to the almanac for 1836*, 5–20, p. 18.
28. A. De Morgan, "Copernicus, Nicolaus", *Penny cyclopaedia*, vii (London, 1837), 498–501, p. 499.
29. A. De Morgan, "On the opinion of Copernicus with respect to the light of the planets", *Monthly notices of the Royal Astronomical Society*, vii (1847), 290–3, p. 293.
30. De Morgan, "Copernicus, Nicolaus" (ref. 28), 499.
31. A. De Morgan, "The progress of the doctrine of the Earth's motion between the times of Copernicus and Galileo, being notes on the ante-Galilean Copernicans", *Companion to the almanac for 1855*, 5–25, pp. 6, 7.
32. *Ibid.*, 22.
33. De Morgan, "Copernicus, Nicolaus" (ref. 28), 501.
34. De Morgan, *op. cit.* (ref. 27), 5.

35. *Ibid.*, 17.
36. De Morgan, *op. cit.* (ref. 31), 12.
37. In his analysis of the views of Francis Bacon, De Morgan defends his anti-Copernicanism from a conviction that he was no more pro-Ptolemy than pro-Aristotle. "In his [Bacon's] ideas of astronomy he perfectly agrees with Ramus, but goes further. It is degraded, he says, by being placed among the mathematical arts, when it should be the noblest part of physics.... We rather suspect, putting all the passages together, that when Bacon impugnes that doctrine as manifestly false which he elsewhere propounds for inquiry, he is taking, for the moment, an advocate's license, in aggravation of the case against the Ptolemaic system.... The whole of what he has said on this subject, when put together, does not justify Hume's assertion that he rejected the Copernican system 'with the most positive disdain.' Like so many others of his day, his view is of one colour or another, according as he is thinking of astronomy or of physics.... We are not among the strongest admirers of Bacon, yet we cannot help thinking that, on this point, he has not been fairly represented" (*ibid.*, 11).
38. De Morgan, *op. cit.* (ref. 27), 11.
39. De Morgan, *op. cit.* (ref. 31), 12.
40. A. De Morgan, "Brahe, Tycho", *Penny cyclopaedia*, v (London, 1836), 323–7, p. 326.
41. A. De Morgan, "Notices of English mathematical and astronomical writers between the Norman Conquest and the year 1600", *Companion to the almanac for 1837*, 21–44, p. 35.
42. *Ibid.*, 35.
43. *Ibid.*, 21.
44. Letter from A. De Morgan to J. F. W. Herschel, 21 July 1845. Royal Society Archives: HS.6.224.
45. A. De Morgan, "An account of the speculations of Thomas Wright of Durham", *Philosophical magazine*, 3rd ser., xxxii (1848), 241–52, p. 250.
46. *Ibid.*, 241.
47. De Morgan, *op. cit.* (ref. 24), 90.
48. A. De Morgan, *Newton: his friend: and his niece* (London, 1885), 130.
49. D. Brewster, *The life of Sir Isaac Newton* (London, 1831), 2.
50. *Ibid.*, 217.
51. *Ibid.*, 218.
52. *Ibid.*, 338.
53. *Ibid.*, 218.
54. For a summary of the Newton–Flamsteed dispute, see R. S. Westfall, *Never at rest: A biography of Isaac Newton* (Cambridge, 1980), 541–50, 655–66.
55. J. Gascoigne, "From Bentley to the Victorians: The rise and fall of British Newtonian natural theology", *Science in context*, ii (1988), 219–56, p. 219.
56. R. Yeo, "Genius, method, and morality: Images of Newton in Britain, 1760–1860", *Science in context*, ii (1988), 257–84, p. 271.
57. G. N. Cantor, "Between rationalism and romanticism: Whewell's historiography of the inductive sciences", in M. Fisch and S. Schaffer (eds), *William Whewell: A composite portrait* (Oxford, 1991), 67–86, p. 80.
58. W. Whewell, *History of the inductive sciences* (London, 1837), ii, 198.
59. S. E. De Morgan, *Memoir of Augustus De Morgan* (London, 1882), 256.
60. A. De Morgan, "Newton", *The Cabinet Portrait Gallery of British worthies*, xi (London, 1846), 78–117, p. 98.

61. William Whiston (1667–1752) succeeded Newton as Lucasian Professor of Mathematics at Cambridge in 1703. He was removed from his chair in 1710 on the grounds of being an Arian. In 1720, Newton used his position as President of the Royal Society to block a proposal to make him a Fellow.
62. De Morgan, “Newton” (ref. 60), 100.
63. A report published by the Royal Society in 1712, when Newton was President, which concluded that not only was Newton the first inventor of the calculus (or method of fluxions), but that it was certainly possible for Leibniz to have received hints that materially affected the creation of his own algorithm.
64. A. De Morgan, “On a point connected with the dispute between Keill and Leibnitz about the invention of fluxions”, *Philosophical transactions of the Royal Society*, cxxxvi (1846), 107–9, p. 107.
65. *Ibid.*, 108.
66. *Ibid.*
67. *Ibid.*
68. De Morgan, *op. cit.* (ref. 48), 132.
69. A. De Morgan, “On the additions made to the second edition of the *Commercium Epistolicum*”, *Philosophical magazine*, 3rd ser., xxxii (1848), 446–56, p. 447.
70. A. De Morgan, “A comparison of the first and second editions of the *Commercium Epistolicum*”, 1–12, f. 11. Royal Society Archives: AP.29.2.
71. Letter from S. Hunter Christie to A. De Morgan, 25 Feb. 1848. Pasted in J. Collins, *Commercium epistolicum...* (London, 1712), University of London Library, shelf mark: [De M] L (BP 1), Secondary Strong Room.
72. Referee’s report from G. Peacock to S. Hunter Christie, 16 Oct. 1847. Royal Society Archives: RR.1.57.
73. *Ibid.*
74. Letter from S. Hunter Christie to A. De Morgan, 25 Feb. 1848. Pasted in Collins, *Commercium epistolicum...* (ref. 71).
75. This did not prevent its being cited in C. R. Weld, *A history of the Royal Society* (London, 1848), i, 417, note 38.
76. De Morgan, *op. cit.* (ref. 48), 135.
77. A. De Morgan, handwritten note, dated 10 Oct. 1848, in Collins, *Commercium epistolicum...* (ref. 71).
78. De Morgan, *op. cit.* (ref. 69), 450.
79. *Ibid.*, 447.
80. De Morgan, *op. cit.* (ref. 64), 108.
81. A. De Morgan, “A short account of some recent discoveries in England and Germany relative to the controversy on the invention of fluxions”, *Companion to the almanac for 1852*, 5–20, p. 8.
82. C. I. Gerhardt (ed.), *Leibnizens mathematische Schriften* (2 vols, Berlin, 1849–50).
83. De Morgan, *op. cit.* (ref. 81), 17.
84. *Ibid.*, 17–18.
85. D. Brewster, *Memoirs of the life, writings, and discoveries of Sir Isaac Newton* (Edinburgh, 1855), ii, 75.
86. *Ibid.*, i, p. xiii.
87. *Ibid.*

88. D. Brewster, *The life of Sir Isaac Newton* (London, 1831), 218; D. Brewster, *Memoirs of the life, writings, and discoveries of Sir Isaac Newton* (Edinburgh, 1855), ii, 83.
89. P. Theerman, "Unaccustomed role: The scientist as historical biographer — two nineteenth century portrayals of Newton", *Biography*, viii (1985), 145–62, pp. 146, 158–9.
90. Letter from A. De Morgan to Lord Brougham, 16 May 1855. University College London Archives: Brougham Correspondence, no. 10,299.
91. Letter from W. Whewell to A. De Morgan, 2 Sept. 1856. University of London Library: MS 775/370/34/1.
92. A. De Morgan, Review of Brewster's *Memoirs of the life of Sir Isaac Newton*, *North British review*, xxiii (1855), 307–38, p. 310.
93. *Ibid.*, 337.
94. Letter from A. De Morgan to D. Brewster (?), n.d., Royal Astronomical Society Archives.
95. De Morgan, *op. cit.* (ref. 92), 321.
96. S. E. De Morgan, *op. cit.* (ref. 59), 263.
97. For an assessment of Brewster's historical work, see J. R. R. Christie, "Sir David Brewster as an historian of science", in A. D. Morrison-Low and J. R. R. Christie (eds), *Martyr of science: Sir David Brewster 1781–1868* (Edinburgh, 1984), 53–56.
98. Letter from A. De Morgan to J. F. W. Herschel, 29 August 1867. Royal Society Archives: HS.6.396.
99. A. De Morgan, "Lord Halifax and Mrs. Catherine Barton", *Notes and queries*, 1st ser., viii, no. 210 (5 Nov. 1853), 429–33, p. 429.
100. *Ibid.*, 429.
101. *Ibid.*, 432.
102. *Ibid.*
103. A. De Morgan, "Lord Halifax and Mrs. Catherine Barton", *Notes and queries*, 2nd ser., ii, no. 35 (30 Aug. 1856), 161–3, p. 161.
104. *Ibid.*, 163.
105. S. E. De Morgan, *op. cit.* (ref. 59), 264.
106. F. Manuel, *A portrait of Isaac Newton* (Cambridge, Mass., 1968), p. viii, quoted in Theerman, *op. cit.* (ref. 89), 154.
107. Letter from G. Peacock to A. De Morgan, 8 Sept. 1856. University of London Library: MS 775/370/28.
108. Yeo, *op. cit.* (ref. 56), 278–9.
109. R. Yeo, *Defining science: William Whewell, natural knowledge, and public debate in early Victorian Britain* (Cambridge, 1993), 144.
110. De Morgan, *op. cit.* (ref. 48), 140.
111. J. L. Richards, "Augustus De Morgan, the history of mathematics, and the foundations of algebra", *Isis*, lxxviii (1987), 7–30, p. 17.
112. A. De Morgan, *Arithmetical books* (London, 1847), p. xiv.
113. *Ibid.*, p. xvii.
114. G. Libri, *Histoire des sciences mathématiques en Italie* (Paris, 1838), ii, 46.
115. A. De Morgan, "On the invention of the signs + and –; and on the sense in which the former was used by Leonardo da Vinci", *Philosophical magazine*, 3rd ser., xx (1842), 136–7.
116. A. De Morgan, "On the early history of the signs + and –", *Transactions of the Cambridge Philosophical Society*, xi (1864), 203–12, p. 203.
117. A. De Morgan, "History of the signs + and –", *The Athenaeum*, no. 1925 (17 Sept. 1864), 376.

118. De Morgan, *op. cit.* (ref. 116), 203.
119. Letter from A. De Morgan to J. F. W. Herschel, 13 Sept. 1864. Royal Society Archives: HS.6.374.
120. De Morgan, *op. cit.* (ref. 117), 376.
121. Graves had also been a colleague of De Morgan at University College from 1839 to 1843, when he held the Professorship of Jurisprudence.
122. Letter from J. T. Graves to A. De Morgan, 27 Sept. 1864. University of London Library: MS 321/3.
123. De Morgan, *op. cit.* (ref. 117), 376.
124. De Morgan, *op. cit.* (ref. 116), 210.
125. *Ibid.*, 212.
126. De Morgan, *op. cit.* (ref. 112), 19.
127. De Morgan, *op. cit.* (ref. 116), 206.
128. *Ibid.*, 210. For a pertinent criticism of De Morgan's opinions in this area, see J. W. L. Glaisher, "On the early history of the signs + and – and on the early German arithmeticians", *Messenger of mathematics*, li (1921–22), 1–148.
129. A. De Morgan, "On some points in the history of arithmetic", *Companion to the almanac for 1851*, 5–18.
130. A. De Morgan, "Viga Ganita", *Penny cyclopaedia*, xxvi (London, 1843), 318–25.
131. A. De Morgan, "On ancient and modern usage in reckoning", *Companion to the almanac for 1850*, 5–34, p. 11.
132. *Ibid.*, 13.
133. *Ibid.*, 17.
134. *Ibid.*, 26.
135. *Ibid.*
136. A. De Morgan, *op. cit.* (ref. 112), pp. vi, vii.
137. A. De Morgan, "On the earliest printed almanacs", *Companion to the almanac for 1846*, 1–31, p. 1.
138. A. De Morgan, "Cocker, Edward", *Penny cyclopaedia*, vii (London, 1837), 312.
139. Letter from J. O. Halliwell to A. De Morgan, n.d., pasted in J. Hawkins, *Cocker's Arithmetick*, 20th edn (London, 1700), University of London Library, shelf mark: [De M] L1 [Cocker], Secondary Strong Room.
140. *Historical Society of Science* [prospectus] (London, 1840?).
141. *Historical Society of Science* [List of Members] (London, 1840?), 5–9.
142. Letter from A. De Morgan to A. Lovelace, July (?) 1840. Bodleian Library, Oxford. Dep. Lovelace Byron 170, ff. 1–2.
143. For a selection of letters from Ada to De Morgan, see B. A. Toole, *Ada: the enchantress of numbers: a selection from the letters of Lord Byron's daughter and her description of the first computer* (Mill Valley, Calif., 1992).
144. Other articles on Halliwell and the Historical Society of Science include H. W. Dickinson, "J. O. Halliwell and the historical society of science", *Isis*, xviii (1932), 127–32, and T. Hornberger, "Halliwell-Phillips and the history of science", *Huntingdon Library quarterly*, xii (1949), 391–9.
145. See *Statement in answer to reports which have been spread abroad against Mr. James Orchard Halliwell* (London, 1845) and A. N. L. Munby, *The history and bibliography of science in England: The first phase, 1833–1845* (Berkeley, 1968).

146. J. O. Halliwell (ed.), *A collection of letters illustrative of the progress of science in England from the reign of Queen Elizabeth to that of Charles the Second* (London, 1841), p. ix.
147. A. De Morgan, "References for the history of the mathematical sciences", *Companion to the almanac for 1843*, 40–65, pp. 40, 41.
148. Letter from A. De Morgan to J. F. W. Herschel, 11 Jan. 1847. Royal Society Archives: HS.6.233.
149. De Morgan, *op. cit.* (ref. 112), p. i.
150. Letter from G. Peacock to A. De Morgan, 2 April 1847. University of London Library: MS 776/3, f.19.
151. De Morgan, *op. cit.* (ref. 112), p. xiv.
152. *Ibid.*, p. ii.
153. R. Witt, *Arithmetical questions...* (London, 1613). See De Morgan, *op. cit.* (ref. 112), 33.
154. *Ibid.*, p. xxviii.
155. *Ibid.*, p. xxviii.
156. *Ibid.*, 96.
157. De Morgan, *op. cit.* (ref. 81), 8.
158. A. De Morgan, "On the difficulty of correct descriptions of books", *Companion to the almanac for 1853*, 5–19, p. 5.
159. De Morgan, *op. cit.* (ref. 137), 1.
160. De Morgan, *op. cit.* (ref. 158), 16. For a criticism of De Morgan's views concerning the first English translation of Euclid, see R. C. Archibald, "The first translation of Euclid's Elements into English and its source", *American mathematical monthly*, lvii (1950), 443–52.
161. De Morgan, *op. cit.* (ref. 158), 11.
162. *Ibid.*, 12.
163. De Morgan, *op. cit.* (ref. 112), p. iii.
164. Letter from A. De Morgan to Lord Brougham, 13 Aug. 1863. University College London Archives: Brougham Correspondence, no. 10,307.
165. A. De Morgan, *op. cit.* (ref. 24, 1872), 301.
166. *Ibid.*, 255.
167. S. E. De Morgan, "Editor's Preface", *ibid.*, p. vi.
168. *Ibid.*, p. v.
169. R. Yeo, *Defining science: William Whewell, natural knowledge, and public debate in early Victorian Britain* (Cambridge, 1993), 149.
170. Richards, *op. cit.* (ref. 111), 17.
171. A. De Morgan, "Speech of Professor De Morgan, President, at the first meeting of the Society, January 16th, 1865", *Proceedings of the London Mathematical Society*, 1st ser., i (1866), 1–9, p. 8.
172. A. De Morgan (ed. by P. Heath), *On the syllogism, and other logical writings* (London, 1966), pp. xi–xxiv.
173. De Morgan, *op. cit.* (ref. 112), p. ii.
174. For a treatment of religious inclination with respect to English nineteenth-century mathematicians (including De Morgan, Peacock and Whewell), see J. L. Richards, "God, truth, and mathematics in nineteenth century England", in M. J. Nye *et al.* (eds), *The invention of physical science* (Amsterdam, 1992), 51–78.
175. I. Todhunter, *A history of the mathematical theory of probability from the time of Pascal to*

- that of Laplace* (Cambridge and London, 1865), p. xii.
176. I. Todhunter, *A history of the mathematical theories of attraction and the figure of the Earth, from the time of Newton to that of Laplace* (London, 1873), ii, 29.
 177. W. W. Rouse Ball, *A short account of the history of mathematics*, 3rd edn (London, 1901), 482; Rouse Ball, *op. cit.* (ref. 4), 133.
 178. W. W. Rouse Ball, "Augustus De Morgan", *The mathematical gazette*, viii (1915–16), 42–45, p. 43.
 179. *Ibid.*, 44.
 180. D. E. Smith, *Rara arithmetica*, 4th edn (New York, 1970), p. xii.
 181. Smith was less complimentary, however, about De Morgan's historical articles, describing them as "not only eccentric but unreliable" (D. E. Smith, *History of mathematics*, i (New York, 1958), 462).
 182. P. E. B. Jourdain, "Editor's Preface", in A. De Morgan, *Essays on the life and work of Newton* (Chicago and London, 1914), p. x.
 183. Rouse Ball, *op. cit.* (ref. 4), 133.
 184. De Morgan, *op. cit.* (ref. 171), 6.
 185. De Morgan, *op. cit.* (ref. 129), 14.
 186. De Morgan, *op. cit.* (ref. 31), 21.